INSTITUTO DE AGROQUÍMICA Y TECNOLOGÍA DE ALIMENTOS

INFLUENCIA DE LA GRASA EN LAS PROPIEDADES FÍSICAS Y SENSORIALES DE GALLETAS. ALTERNATIVAS PARA LA MEJORA DEL PERFIL DE ACIDOS GRASOS

Tesis Doctoral

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Valencia, Julio 2013

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

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HACEN CONSTAR:

Que la memoria titulada **"Influencia de la grasa en las propiedades físicas y sensoriales de galletas. Alternativas para la mejora del perfil de ácidos grasos"** que presenta Dª Paula Tarancón Serrano para optar al grado de Doctor por la Universidad Politécnica de Valencia, ha sido realizada bajo su dirección en el Instituto de Agroquímica y Tecnología de Alimentos (CSIC) y que reúne las condiciones para ser defendida por su autora.

Valencia, 7 de junio de 2013

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Agradezco a Ana Salvador y Teresa Sanz por darme la oportunidad de realizar esta tesis y por su ayuda, confianza y apoyo a lo largo de todo el proceso.

A Amparo Tárrega, por su dedicación, ilusión y paciencia infinita. Por todo lo que me ha enseñado y por animarme siempre a sacar lo mejor de mí misma. He sido muy afortunada de poder trabajar con ella.

A la Dra. Susana Fiszman por su colaboración en esta tesis doctoral y por brindarme la ocasión de asistir a cursos y eventos de carácter científico que han sido de gran ayuda para mi formación.

A todos los catadores que han participado en los estudios sensoriales ya que sin ellos este trabajo no habría sido posible.

A todas mis compañeras del laboratorio que han hecho que todo este tiempo haya sido también una gran experiencia a nivel personal.

A Eva García, directora de mi trabajo final de carrera y amiga, ya que gracias a ella emprendí este proyecto-aventura que ha sido la realización de la tesis doctoral.

A mi familia y, en especial a mi madre, por su apoyo incondicional y simplemente por estar ahí, siempre.

RESUMEN

La presente tesis doctoral se ha centrado en el desarrollo de nuevas formulaciones de galletas con un perfil de ácidos grasos saludable y contenido en grasa reducido mediante el uso de sistemas aceite vegetal/gel de hidrocoloide como sustituto de la grasa convencional.

En un primer estudio exploratorio se evaluó el efecto del reemplazo de mantequilla por sistemas elaborados con aceite de girasol y distintos éteres de celulosa con una disminución importante del contenido en grasa de la galleta (del 18% al 10.6%) Se evaluó si el grado de metoxil e hidroxipropil sustitución de estos éteres de celulosa afectó a la textura y aceptabilidad de galletas horneadas, así como los cambios producidos en las propiedades reológicas en la masa de galletas debidos a dicha sustitución. Los resultados de los ensayos reológicos indicaron que la estructura de las formulaciones con sistemas de aceite de girasol/gel presentaban un comportamiento más próximo a una estructura líquida y que el grado de metoxil e hidroxipropil sustitución de la celulosa no afectó a las propiedades reólogicas de las masas de galleta. Por otro lado, se observó que las masas elaboradas con los sistemas aceite de girasol/gel presentaron menor resistencia a la deformación en comparación con las masas elaboradas con mantequilla lo cual indicó la menor elasticidad de las masas elaboradas con los sistemas aceite de girasol/gel y que esta elasticidad estuvo relacionada con la expansión de la masa tras el horneado. En cuanto a las propiedades mecánicas de las galletas horneadas, en general, no hubo apenas diferencias entre los valores de fuerza máxima de rotura y los de fuerza máxima de penetración entre los distintos sistemas de aceite de girasol/gel con respecto a las galletas elaboradas con mantequilla. La aceptabilidad de las galletas con los distintos éteres de celulosa presentó diferencias con las galletas elaboradas con mantequilla, principalmente en cuanto a la aceptabilidad global y a la textura y, en menor medida, al sabor.

Por ello, la segunda parte de la tesis se dedicó a estudiar en profundidad los cambios sensoriales que el consumidor percibe en la galleta cuando se sustituye la grasa convencional (de origen lácteo o vegetal) por distintos sistemas aceite/gel de hidrocoloide. En este caso se consideró, además del aceite de girasol y la hidroxipropilmetilcelulosa, otras alternativas como el aceite de oliva y la goma xantana y distintos niveles de cantidad de grasa en la galleta (18; 15,6 y 10,6%). Mediante la técnica de perfil de libre elección se describieron los cambios en las propiedades sensoriales de las galletas percibidas por los consumidores al variar el tipo y la cantidad de grasa. Se planteó una modificación de la técnica para poder estudiar las diferencias en la textura y sabor a lo largo del proceso de masticación y se observó que la complejidad de las diferencias que los consumidores percibieron entre las distintas muestras fue mayor a medida que avanzaba el proceso de consumo. Los resultados mostraron que en galletas con grasa convencional, una disminución elevada del contenido de grasa (del 18 al 10,6%) dio lugar a galletas considerablemente más duras, secas y con menos sabor. En cambio, con una reducción un poco menos drástica (del 18 al 15,6%), las propiedades sensoriales de las galletas fueron similares. Las galletas elaboradas con sistemas con goma xantana (con aceite de girasol o de oliva) presentaron las características sensoriales que más diferían de las galletas elaboradas con la grasa convencional. En cambio, las galletas elaboradas con los sistemas de aceite de oliva y girasol, ambos con hidroxipropilmetilcelulosa, presentaron características sensoriales similares a las de las galletas elaboradas con mantequilla o margarina. Posteriormente, se evaluaron los cambios en las propiedades mecánicas y acústicas de las galletas y se estableció su relación con las propiedades de textura percibidas por los consumidores. Al disminuir el contenido en grasa, las galletas presentaron mayores valores de fuerza de resistencia a la rotura y a la penetración y también más fracturas durante la penetración con cilindro lo que explicó que en boca fueran percibidas como más duras y crujientes. Además, en general, al disminuir el contenido de grasa, o al sustituirla por los sistemas de aceite vegetal/gel, el número de eventos de fuerza durante la penetración con esfera disminuyó y las galletas fueron percibidas como menos desmigables o quebradizas. En general, las galletas con los sistemas de aceite vegetal/hidroxipropilmetilcelulosa confirieron propiedades mecánicas y acústicas similares a las presentadas por las galletas con grasa convencional, dando lugar a galletas con propiedades de textura similares en boca.

Finalmente, la última parte de la tesis se dedicó a evaluar la aceptabilidad de los consumidores de las galletas elaboradas con los sistemas de hidroxipropilmetilcelulosa y aceite de oliva o de girasol. La aceptabilidad de las galletas varió entre los consumidores y mediante análisis de conglomerados se detectaron tres grupos de consumidores con diferentes patrones de preferencia. El estudio de la relación entre la aceptabilidad y las carácteristicas sensoriales percibidas por cada consumidor utilizando la técnica CATA (*Check all that apply*) permitió determinar los atributos responsables del agrado o rechazo de las galletas para cada grupo de consumidores. Para el primer grupo de consumidores, las galletas preferidas fueron las elaboradas con aceite de oliva y con mantequilla a nivel de grasa alto, las cuales fueron percibidas como fáciles de masticar, fáciles de tragar, crujientes y con sabor intenso a galleta. El segundo grupo de consumidores prefirió las galletas con mantequilla que fueron percibidas como crujientes, fáciles de masticar y con sabor intenso a galleta. Para los consumidores del tercer grupo, la aceptabilidad estuvo relacionada con el sabor a mantequilla, al sabor a tostado y el sabor intenso a galleta que fueron percibidos en las galletas con aceite de oliva y girasol con contenido alto en grasa. Por tanto, mientras que para los dos primeros grupos, tanto las características de textura como el sabor influyeron en la aceptabilidad, para los consumidores del tercer grupo, fue el sabor el atributo que más influyó en la aceptabilidad de las galletas.

Por último, se llevó a cabo un estudio de expectativas para evaluar el efecto de la información nutricional de la etiqueta en la aceptabilidad de las galletas y la percepción de saludable de los consumidores. La declaración en la etiqueta de galletas “con aceite de oliva” y del “bajo contenido de grasa saturadas” aumentó de forma importante la expectativa hedónica y la percepción de saludable de los consumidores. La aceptabilidad final de las muestras dependió de cuánto le gustó al consumidor tanto la galleta como la información de la etiqueta. Sin embargo la percepción de saludable sólo dependió de la información de la etiqueta y no se vio afectada por las características sensoriales de las galletas.

SUMMARY

The research of this thesis has focused on the development of biscuit formulations with a healthy fatty acid profile and reduced fat content by using a vegetable oil/hydrocolloid gel system as a replacement of shortening.

First, the effect of the replacement of butter with sunflower oil and different cellulose ethers and an important decrease in the biscuit fat content (from 18 to 10.6%) was evaluated. The effect of the degree of methoxyl and hydroxypropil methyl substitution on i) dough rheological properties; ii) baked biscuit texture and iii) consumer acceptance was evaluated.

The rheological essay results showed that the structure of sunflower oil/gel systems presented a closer behaviour to a liquid structure and that the degree of methoxyl and hydroxypropil methyl substitution did not affect the rheological properties of the dough. On the other hand, sunflower oil/gel system dough types presented lower resistance to deformation than dough prepared with butter, indicating that the sunflower oil/gel system dough types were less elastic and that this elasticity was related with the dough spread after baking.

Regarding mechanical properties of baked biscuits, in general, there were hardly any differences among the different sunflower oil/ gel systems and butter biscuits with regard to the values of maximum force at breaking and the maximum force values at penetration. The biscuits made with the sunflower oil/gel systems, each one containing a different cellulose ether, showed differences in consumers acceptability compared to the biscuits made with butter; mainly in the overall acceptability and the texture and, to a lesser extent, in flavour.

Therefore, in the second part of this thesis, the sensory changes perceived by consumers when shortening (dairy or vegetable origin) is replaced by different oil/gel systems in biscuits were studied in depth. In this part, apart from sunflower oil and hydroxipropilmethylcellulose, olive oil, xanthan gum and different fat contents (18; 15.6 y 10.6%) were also considered. By using the free choice profile method, the changes in the sensory properties of the biscuits

perceived by consumers were evaluated when fat type and content varied. A modification of the technique was proposed to study the texture and flavour differences perceived during the whole eating process and, it was observed that the complexity of the differences found by consumers in the different samples increased as the eating process progressed. Results showed that in shortening biscuits an important decrease in the fat content (from 18 to 10.6%) led to biscuits that were perceived as harder, drier and with less flavour. However, with a less drastic fat reduction (from 18 to 15.6%), the sensory properties of the biscuit were similar in either fat content studied.

The xanthan- gum- system biscuits (with both olive and sunflower oil) were those that differed most in sensory characteristics from shortening biscuits. Nevertheless, hydroxipropilmethilcellulose- system biscuits made with both olive and sunflower oil presented similar sensory characteristics to shortening ones. Subsequently, the changes in mechanical and acoustical properties were evaluated as well as the relationship between these properties and the sensory texture perceived by consumers.

When reducing the fat content, biscuits presented higher values of the breaking strength and penetration and also a higher number of fractures during the penetration with a cylindrical probe, which explained the more intense sensation of hardness and crunchiness perceived in the mouth. Moreover, in general, the fat content reduction or the oil/gel system replacement, led to a decrease in the number of force events during biscuit penetration with the spherical probe and they were perceived less mealy and crumbly.

In general, the use of oil/hydroxipropilmethilcellulose systems conferred similar mechanical and acoustical properties when compared to biscuits made with shortening, leading to biscuits with similar textural properties perceived in the mouth.

Finally, the last part of the research work included in this thesis, was the evaluation of consumer acceptability of the oil/gel systems biscuits prepared with hydroxipropilmethilcellulose and olive oil or sunflower oil.

Biscuit’ acceptability varied among consumers and, by using cluster analysis, three groups of consumers with different preference patterns were identified. The study of the relationship between acceptability data and the sensory characteristics perceived by each individual, using the Check All That Apply method, identified the attributes related to the liking or disliking of the biscuits by each consumer group.

For the first group of consumers, the preferred biscuits were those prepared with olive oil and butter at a high fat content which were perceived as easy to chew, easy to swallow, crispy and as having biscuit flavour.

The second group of consumers preferred butter biscuits which were perceived as crispy, easy to chew and as having biscuit flavour.

For consumers of the third group, liking was related to butter flavour, roasted flavour and biscuit flavour which were perceived in olive oil and sunflower oil biscuits at high fat content. Thus, while for the first and second group, texture and flavour characteristics affected liking; for the third group of consumers, the flavour was the trait that affected liking to a higher extent.

Finally, an expectation study was to carried out to evaluate the effect of the nutritional information displayed on the biscuit label on consumers liking and on consumer.perception of biscuit healthiness.

The label claims “with olive oil” and “low saturated fat content” increased the hedonic expectation considerably as well as perceived healthiness of biscuits. The actual liking of biscuits depended on both the sensory quality of the samples and the information provided. However, the perception of biscuits healthiness was based on the label information alone and the hedonic characteristics of the samples did not affect it.

RESUM

La present tesi doctoral s'ha centrat en el desenvolupament de noves formulacions de galetes amb un perfil d'àcids grassos saludable i contingut en greix reduït mitjançant l'ús de sistemes oli vegetal/gel de hidrocol-loide com a substitut del greix convencional.

En un primer estudi exploratori es va avaluar l'efecte del reemplaçament de mantega per sistemes elaborats amb oli de girasol i diferents èters de cel·lulosa amb una disminució important del contingut en greix de la galeta (del 18% al 10.6%) Es va avaluar si el grau de metoxil i hidroxipropil substitució d'aquests èters de cel·lulosa va afectar a la textura i acceptabilitat de galetes, així com els canvis produïts en les propietats reològiques en la massa de galetes deguts a aquesta substitució. Els resultats dels assajos reològics van indicar que l'estructura de les formulacions amb sistemes d'oli de girasol/gel presentaven un comportament més pròxim a una estructura líquida i que el grau de metoxil i hidroxipropil substitució de la cel·lulosa no va afectar a les propietats reólogiques de les masses de galeta. D'altra banda, es va observar que les masses elaborades amb els sistemes oli de girasol/gel van presentar menor resistència a la deformació en comparació amb les masses elaborades amb mantega la qual cosa va indicar la menor elasticitat de les masses elaborades amb els sistemes oli de girasol/gel i que aquesta elasticitat va estar relacionada amb l'expansió de la massa després de l’enfornat. Quant a les propietats mecàniques de les galetes, en general, no va haver-hi diferències significatives entre els valors de força màxima de trencament i els de força màxima de penetració entre els diferents sistemes d'oli de girasol/gel pel que fa a les galetes elaborades amb mantega. L'acceptabilitat de les galetes amb els diferents èters de cel·lulosa va presentar diferències amb les galetes elaborades amb mantega, principalment quant a l'acceptabilitat global i a la textura i, en menor mesura, al sabor.

Per açò, la segona part de la tesi es va dedicar a estudiar en profunditat els canvis sensorials que els consumidor perceben quan en la galeta se substitueix el greix convencional (d'origen làctic o vegetal) per diferents sistemes oli/gel de hidrocol-loide. En aquest cas es va considerar, a més de l'oli de girasol i la hidroxipropilmetilcelulosa, altres alternatives com l'oli d'oliva i la goma xantana i diferents nivells de quantitat de greix en la galeta (18, 15,6 i 10,6%). Mitjançant la tècnica de perfil de lliure elecció es van descriure els canvis en les propietats sensorials de les galetes percebudes pels consumidors en variar el tipus i la quantitat de greix. Es va plantejar una modificació de la tècnica per a poder estudiar les diferències en la textura i sabor al llarg del procés de masticació i es va observar que la complexitat de les diferències que els consumidors van percebre entre les diferents mostres va ser major a mesura que avançava el procés de consum. Els resultats van mostrar que en galetes amb greix convencional, una disminució elevada del contingut de greix (del 18 al 10,6%) va donar lloc a galetes considerablement més dures, seques i amb menys sabor. En canvi, les galetes elaborades amb els sistemes d'oli d'oliva i girasol, tots dos amb hidroxipropilmetilcelulosa, van presentar característiques sensorials similars a les de les galetes elaborades amb mantega o margarina. Posteriorment, es van avaluar els canvis en les propietats mecàniques i acústiques de les galetes i es va establir la seua relació amb les propietats de textura percebudes pels consumidors al disminuir el contingut en greix, les galetes van presentar majors valors de força de resistència al trencament i a la penetració i també més fractures durant la penetració amb cilindre el que va explicar que en boca anaren percebudes com més dures i cruixents. A més, en general, en disminuir el contingut de greix, o en substituir-la pels sistemes d'oli vegetal/gel, el nombre d'esdeveniments de força durant la penetració amb esfera va disminuir i les galetes van ser percebudes com menys trencadisses i esmollables. En general, les galetes amb els sistemes d'oli vegetal/hidroxipropilmetilcelulosa van conferir propietats mecàniques i acústiques similars a les presentades per les galetes amb greix convencional, donant lloc a galetes amb propietats de textura similars en boca.

Finalment, l'última part de la tesi es va dedicar a avaluar l'acceptabilitat dels consumidors de les galetes elaborades amb els sistemes de hidroxipropilmetilcelulosa i oli d'oliva o de girasol. L'acceptabilitat de les galetes va variar entre els consumidors i mitjançant anàlisis de conglomerats es van detectar tres grups de consumidors amb diferents patrons de preferència. L'estudi de la relació entre l'acceptabilitat i les prpietats sensorials percebudes per cada consumidor utilitzant la questio CATA (Check all that apply) va permetre determinar els atributs responsables del grat o rebuig de les galetes per a cada grup de consumidors. Per al primer grup de consumidors, les galetes preferides van ser les elaborades amb oli d'oliva i amb mantega a nivell de greix alt, les quals van ser percebudes com fàcils de mastegar, fàcils d'engolir, cruixents i amb sabor intens a galeta. El segon grup de consumidors va preferir les galetes amb mantega que van ser percebudes com a cruixents, fàcils de mastegar i amb sabor intens a galeta. Per als consumidors del tercer grup, l'acceptabilitat va estar relacionada amb el sabor a mantega, al sabor a torrat i el sabor intens a galeta que van ser percebuts en les galetes amb oli d'oliva i girasol amb contingut alt en greix. Per tant, mentre que per als dos primers grups, tant les característiques de textura com el sabor van influir en l'acceptabilitat, per als consumidors del tercer grup, els atributs de sabor van ser els que més van influir en l'acceptabilitat de les galetes.

Finalment, es va dur a terme un estudi d'expectatives per avaluar l'efecte de la informació nutricional de l'etiqueta en l'acceptabilitat de les galetes i la percepció de saludable dels consumidores. La declaració en l'etiqueta de galetes “amb oli d'oliva” i de el “baix contingut de greix saturades” va augmentar de forma important l'expectativa hedònica i la percepció de saludable dels consumidors. L'acceptabilitat final de les mostres va dependre de quant li va agradar al consumidor tant la galeta com la informació de l'etiqueta. No obstant açò la percepció de saludable només va dependre de la informació de l'etiqueta i no es va veure afectada per les característiques sensorials de les galetes.

ÍNDICE GENERAL

INTRODUCCIÓN GENERAL

Importancia de la grasa en la dieta y la salud

En los últimos años se han producido cambios sustanciales en la dieta de la población de los países industrializados. En líneas generales, se ha producido un aumento de la ingesta calórica total, un aumento del consumo de proteínas y de grasas y una reducción en la ingesta de hidratos de carbono complejos, fibra, vegetales y frutas. Además, los cambios en los hábitos de la población han producido también cambios cualitativos en cuanto a la fuente y tipo de macronutrientes. Estos cambios en la dieta se han asociado a problemas en la salud y se ha generado como consecuencia un aumento de la concienciación social de la necesidad de introducir una dieta y unos hábitos más saludables.

Uno de los temas que ha adquirido un protagonismo importante es la composición de la grasa. Esto se debe a la baja calidad de la grasa en la dieta asociada al aumento del consumo de productos manufacturados y al cambio en los aceites utilizados y en las formas de cocinar. En general, el consumo excesivo de grasa ha dado lugar a que cada vez sea mayor el número de personas con sobrepeso y obesidad así como con enfermedades cardiovasculares. Por ello, organizaciones como la OMS y la FAO recomiendan que el consumo de grasas sea inferior al 30% de la ingesta de calorías totales y que de éstas menos del 10% sean grasas saturadas (Dietary Guidelines Advisory Committee, 2005). Diversas organizaciones e instituciones relacionadas con la alimentación y la nutrición han puesto en marcha actuaciones cuyo objetivo es promover la reformulación de alimentos. Así en 2007, el Ministerio de Sanidad y Consumo tomó la iniciativa de promover hábitos alimenticios saludables, con especial atención en el problema de la obesidad infantil. En concreto se ha prestado especial importancia al desayuno, por la importancia de esta primera comida del día en el ámbito de la prevención. Las recomendaciones aconsejan un desayuno variado y completo para toda la población que incluya productos lácteos, fruta y, por supuesto, un derivado de cereales. Reducir el contenido en grasa, así como mejorar la calidad de ésta en productos consumidos habitualmente en el desayuno, como las galletas, resulta muy interesante ya que de este modo se podría contar con opciones saludables para completar la parte correspondiente al grupo de los cereales.

Función tecnológica de la grasa en los alimentos

Las galletas son productos compuestos por una base de harina que incorpora grasa y azúcar como elementos principales y como opcionales huevos, leche y otros componentes. A diferencia de otros productos como el pan o los bizcochos, las galletas son sistemas de baja humedad en los que la grasa tiene un papel fundamental. Las grasas mejoran la textura, la apariencia, la lubricidad, la sensación en boca y el sabor, contribuyendo así a la palatabilidad del alimento (Drewnowski, 1992; Grigelmo-Miguel, Carrera-Boladeras y Martín-Belloso, 2001; Zoulias, Oreopoulou y Kounalaki, 2002). Además, también aportan volumen a los alimentos, retienen agua, facilitan el mecanismo de transferencia de calor a elevadas temperaturas (Drewnowski, Nordensten y Dwyer, 1998) e incrementan la sensación de saciedad durante la comida (Leland, 1997). Por otro lado, debido a su capacidad disolvente de sustancias sápidas y olorosas son vehículo de moléculas aromáticas liposolubles; asimismo, actúan como precursoras del desarrollo de aromas y sabores y estabilizan el sabor.

La grasa de origen animal que tradicionalmente se ha utilizado en la elaboración de galletas es la mantequilla. La mantequilla es una emulsión de agua en aceite que se forma por inversión de fase cuando se bate la nata. La mantequilla contiene entre un 81-85% de grasa, 14-16% de agua y 0,5-2% de sustancia seca magra y su composición está, en general, regulada legalmente. La fase continua está formada por la fracción líquida de la grasa láctea, en la que se encuentran englobados gránulos de grasa, gotículas de agua y pequeñas burbujas de aire (Belitz y Grosch, 1992). En la Tabla 1 se muestra la composición de ácidos grasos de diferentes grasas y aceites utilizados en la elaboración de galletas. Como indica la tabla, la mantequilla destaca por un elevado contenido de ácidos grasos saturados (aproximadamente 38,4%). Además también es importante destacar el contenido de colesterol (98 mg/100 g grasa) presente en la mantequilla.

Tabla 1. Composición en ácidos grasos de las principales grasas y aceites utilizados en la elaboración de productos de bollería (extraída de Belitz y Grosch (1992).

Tipo de grasa o aceite	Composición en ácidos grasos (%)					
	Mirístico (C 14:0)	Palmítico (C16:0)	Esteárico (C18:0)	Palmitoleico (C16:1)	Oleico (C18:1)	Linoleico (C18:2)
Mantequilla	7-9	23-26	10-13	5	30-40	4-5
Aceite de palma	1-3	34-43	3-6	–	38-40	5-11
Aceite de girasol	–	10-13		–	21-39	51-68
Aceite de soja	0-1	6-10	2-4	–	21-29	50-59

Las grasas de origen vegetal que se suelen utilizar para la elaboración de galletas provienen principalmente del aceite de palma, soja y girasol.

El aceite de palma se produce en países tropicales, se obtiene a partir de la pulpa de la palma y se caracteriza por su bajo precio. Debido a la elevada hidrólisis enzimática que se produce dando lugar a un rápido incremento del contenido en ácidos grasos libres, debe procesarse rápidamente y refinarse. Está compuesto por un 40 % de ácidos grasos saturados lo que lo hace estable y resistente a la oxidación. Asimismo, también tiene una cantidad notable de ácidos grasos monoinsaturados (Tabla 1). Actualmente el aceite de palma es uno de los aceites más consumidos del mundo y además de emplearse para elaborar productos de panadería, pastelería y confitería, también se utiliza para la producción de salsas, sopas instantáneas, platos preparados congelados y deshidratados y como aceite de cocina.

El aceite de soja es el más producido a nivel mundial, es rico en lecitina y vitaminas A, E y D. Tiene un contenido mayoritario en ácidos grasos poliinsaturados (Tabla 1), por lo que no es demasiado estable. Debido a su sabor neutro, es adecuado para la elaboración de margarinas.

El aceite de girasol es uno de los aceites más consumidos en Europa y, al igual que el aceite de soja, tiene un elevado contenido en ácidos grasos poliinsaturados (Tabla 1) y también es adecuado para la elaboración de margarinas.

Las propiedades físicas de las grasas son determinantes en la elaboración de las masas de los productos de panadería y bollería. A nivel tecnológico es fundamental el estado físico de la grasa a temperatura ambiente. Las grasas que son sólidas a temperatura ambiente tienen un mayor contenido de ácidos grasos saturados, mientras que los aceites que son líquidos a temperatura ambiente están compuestos principalmente por ácidos grasos monoinsaturados y poliinsaturados. También es importante destacar que el grado de insaturación de una grasa afecta a su estabilidad; así una grasa con un elevado contenido en ácidos grasos saturados será menos sensible a la oxidación y, por tanto, más estable.

Debido al elevado contenido de sólidos grasos así como de ácidos grasos saturados del aceite de palma, se pueden obtener grasas con consistencia sólida/semisólida sin necesidad de realizar tratamientos a la grasa. En cambio, tanto el aceite de soja como el de girasol han de someterse a procesos de saturación como la hidrogenación o la transesterificación para obtener grasas en el intervalo plástico deseado (punto de fusión y consistencia adecuada) para la elaboración de galletas. Tras estos tratamientos se obtienen margarinas y las denominadas grasas “a la carta” o *shortenings* (grasas plásticas anhidras). Este término se ha acuñado a nivel internacional y hace referencia a la capacidad de la grasa de lubricar, debilitar y acortar la estructura de la matriz alimentaria lo cual confiere las características de textura deseables del producto (Ghotra, Dyal y Narine, 2002). Por otro lado, es importante destacar que durante el proceso de hidrogenación parcial de las grasas destinadas a la elaboración de margarinas se producen alrededor de 1-2% de ácidos grasos trans y en el caso de los *shortenings* industriales se generan 40-60% de estos ácidos grasos (Ovesen, Leth y Hansen, 1998 y Stender, Dyerberg y Astrup, 2006). Los ácidos grasos trans son ácidos grasos no saturados con al menos un doble enlace en configuración trans, que se caracteriza porque los dos átomos de hidrógeno de los carbonos adyacentes al doble enlace se encuentran en direcciones opuestas, a diferencia de lo que ocurre en los ácidos grasos cis que forman parte de las células humanas. Son, por tanto, isómeros geométricos cuya estructura molecular resulta más rígida y les confiere diferentes propiedades físicas, fundamentalmente un punto de fusión más elevado y una mayor estabilidad termodinámica (Valenzuela y Morgado, 1999).

Existen múltiples estudios que han demostrado que el consumo excesivo de ácidos grasos saturados eleva el colesterol y los triglicéridos, lo cual resulta perjudicial para las funciones vasculares; por lo que una elevada ingesta de estas grasas representa un factor de riesgo cardiovascular y puede estar relacionada con un aumento de la resistencia a la insulina y riesgo de padecer diabetes (Micha y Mozaffarian, 2010). Por otro lado, se ha demostrado que los ácidos grasos trans, tienen efecto hipercolesteromiante, aumentan los niveles de lipoproteínas de baja densidad (LDL) y pueden estar relacionados con la desarrollo de la arteriosclerosis (Kummerow, 1981). Por estas razones, en 2003 la OMS publicó un informe en el que se recomendaba que el consumo de ácidos grasos trans provenientes de aceites hidrogenados industrialmente debía ser menor al 1% de la ingesta energética total (WHO, 2003).

Como se ha comentado anteriormente, la funcionalidad de grasas como la mantequilla, los *shortenings* comerciales o la manteca de cerdo radica en su capacidad de impartir *shortening* a la masa de productos de bollería lo cual se atribuye a sus propiedades físicas y, en particular, a su plasticidad y elasticidad las cuales evitan la formación de la red de gluten (Weiss, 1970). Debido a la plasticidad de estas grasas las partículas de gluten quedan recubiertas evitando así el entrecruzamiento de las proteínas que forman el gluten dando lugar a una masa corta y con textura desmenuzable. Las propiedades elásticas que poseen las grasas sólidas junto con la capacidad de unión del aceite en la grasa evitan que la fracción líquida de la grasa se filtre a la masa. Además, al ser sólidas, estas grasas actúan como barrera entre distintas capas de masa permitiendo la acción del laminado y haciendo posible la elaboración de productos como croissants y masas hojaldradas (Marangoni, 2012).

En trabajos de investigación recientes en los que se ha estudiado el efecto de la sustitución directa de la grasa saturada por aceite en diversos grupos de alimentos se ha observado que este reemplazo puede dar lugar a una disminución de la calidad de algunos de estos productos. Por ejemplo, debido a la falta de estructura del aceite se observó la migración de aceite y la fuga o filtrado del mismo en chocolate (Hughes, Marangoni, Wright, Rogers y Rush, 2009) o un aumento de la firmeza en productos cárnicos preparados a base de triturados (Youssef y Barbut, 2009). Por lo tanto, la reducción o eliminación de la grasa saturada de los alimentos que componen la dieta supone un reto para la industria de alimentos ya que, por un lado, existe la necesidad de reducir el contenido de estos ácidos grasos para poder ofrecer al consumidor productos más saludables y, por el otro, debido a la funcionalidad de estos ácidos grasos en la elaboración de galletas resulta muy difícil eliminarlos completamente (Marangoni, 2012). La utilización de aceites en la elaboración de una masa de galleta hace que las masas resulten demasiado líquidas o blandas, dificultando así su correcta manipulación (Baltsavias, Jurgens y Van Vliet, 1999). Por ello, cuando el contenido de ácidos grasos saturados o ácidos grasos trans se reduce o se elimina surge la necesidad de explorar métodos alternativos para impartir la estructura necesaria a la grasa para que las funciones de la misma puedan mantenerse (Marangoni, 2012).

Desarrollo de sustitutos de grasa saturada

Con la finalidad de solventar los problemas que surgen en la elaboración de determinados productos cuando se sustituyen las grasas sólidas por aceites con mayor contenido en ácidos grasos insaturados se han planteado diferentes estrategias. Una de estas nuevas estrategias se basa en atrapar el aceite líquido en una red de gel. Así, el aceite adquiere propiedades similares a las de las grasas sólidas y de este modo puede emplearse como sustituto de éstas permitiendo la mejora del perfil de ácidos grasos del producto, y manteniendo las características organolépticas del mismo (Marangoni, 2012). En un trabajo de Gravelle, Barbut y Marangoni (2012), se utilizó etilcelulosa como agente gelificante para formar un oleogel con aceite de colza en el que también se empleó un agente surfactante como agente plastificante. Para la formación de un oleogel estable, en este trabajo, se calentó la solución hasta 140º C (por encima de la temperatura de transición vítrea de la etilcelulosa).

A pesar de que el uso de oleoges o emulsiones se presenta como una posible alternativa para diseñar sustitutos de grasa saturada, existen muy pocos trabajos en los que se haya estudiado su posible aplicación para la elaboración de productos bajos en grasa (Jiménez-Colmenero, 2013). Lobato-Calleros, Recillas-Mota, Espinosa‑Solares, Alvarez‑Ramirez y Vernon‑Carter (2009) y Marquez y Wagner (2010) estudiaron diferentes tipos de emulsiones con el fin de utilizarlas como sustitutos de grasa en productos lácteos y bebidas de soja, respectivamente, para reducir el contenido en grasa y también para obtener productos con un perfil de ácidos grasos más saludable. En estos estudios se analizó la influencia de las emulsiones en parámetros reólogicos y estructurales de los productos resultantes y se prestó menos atención a otros aspectos como la viabilidad tecnológica y sensorial, esenciales a la hora de evaluar las posibilidades reales de estos sustitutos de grasa (Jiménez-Colmenero, 2013).

La elevada hifrofilia y la relativa insolubilidad en aceites vegetales u otros disolventes apolares de los biopolímeros permitidos como ingredientes en la industria alimentaria hacen que la gelificación de aceites vegetales mediante el uso de polímeros se presente como un reto. Hasta ahora, la etilcelulosa ha sido el único polímero que ha presentado características adecuadas para este propósito (Marangoni, 2012).

La metilcelulosa (MC) y la hidroxipropilmetilcelulosa (HPMC) son hidrocoloides utilizados de forma habitual en la industria alimentaria. La MC y la HPMC se obtienen por eterificación de la celulosa. Son capaces de producir una red de gel que estabiliza espumas y emulsiones, modifica la textura, aumenta la viscosidad y aporta fibra dietética (Yánez y Biolley, 1999). Además se caracterizan por su capacidad de termogelificación reversible. Es decir, si una disolución de MC o HPMC se calienta, se produce inicialmente una disminución en la viscosidad. No obstante, si la temperatura continúa aumentando, el polímero forma un gel que revierte al estado inicial al disminuir la temperatura. Otro fenómeno observado al aumentar la temperatura es la precipitación de las moléculas. Ciclos repetidos de enfriamiento y calentamiento no afectan a la capacidad de formación del gel ni a la estabilidad del gel formado (Sarkar, 1979).

La temperatura de formación de gel y las características de los geles desarrollados dependen del tipo y grado de sustitución de la celulosa, del peso molecular y de la presencia de aditivos (Sarkar, 1979). El tipo y grado de sustitución de diferentes éteres de celulosa así como su temperatura de formación de gel y la estructura de éste se presentan en la Tabla 2. En cuanto al tipo de sustitución es interesante destacar que la metoxil sustitución es la responsable de la gelificación de la HPMC, no obstante, la hidroxipropil sustitución altera significativamente las características de la gelificación. Como se indica en la Tabla 2, para un mismo grado de metoxil sustitución, el aumento de la hidroxipropil sustitución produce un aumento en la temperatura de gelificación. Si se mantiene constante la hidroxipropil sustitución y el grado de metoxil sustitución disminuye, se produce un descenso en las interacciones hidrofóbicas que se traduce en un aumento de la temperatura de formación de gel. Por otro lado, la temperatura de gelificación también depende de la concentración ya que a medida que ésta aumenta, se produce una disminución en la temperatura de gelificación.

Tabla 2. Temperatura de formación de gel y tipo de gel en función del tipo y grado de sustitución de diferentes éteres de celulosa (extraído de Sarkar, 1979).

Tipo de éter de celulosa	Grado de metoxil sustitución	Hidroxipropil sustitución molar	Temperatura de formación de gel*	Estructura del gel*
MC	1,6-1,8	0	50-55ºC	Firme
HPMC	1,6-1,8	0,1-0,2	58-64ºC	Semi-firme
HPMC	1,65-1,9	0,2-0,3	62-68ºC	Semi-firme
HPMC	1,1-1,4	0,1-0,3	70-90ºC	Suave

*Solución acuosa al 2%.

Factores que afectan a la aceptación del consumidor

Durante el desarrollo de un nuevo producto la evaluación de su aceptabilidad por los consumidores es importante para conocer las posibilidades de éxito del mismo en el mercado. La respuesta del consumidor frente a un alimento o producto es compleja y viene definida por distintos aspectos a considerar: un aspecto sensorial relacionado con las propiedades del producto; un aspecto afectivo responsable de la respuesta positiva o negativa hacia el producto; un aspecto cognitivo que viene dado por el conocimiento o la opinión que tenga el consumidor acerca del producto y, finalmente, un aspecto relacionado con el comportamiento del consumidor que establecerá qué acciones o intenciones definen su reacción ante una determinada situación (Costell, Tárrega y Bayarri, 2010). La importancia que tiene cada uno de estos aspectos puede variar dependiendo del tipo de producto y a lo largo del tiempo ya que la opinión y actitud del consumidor puede evolucionar. Por lo tanto, en el desarrollo de nuevos productos resulta de interés saber en cada caso cuáles de estas variables tienen un mayor peso y cómo van a influir en mayor medida en la aceptabilidad del consumidor.

Cuando debido a cambios en la formulación o en el procesado se producen diferencias perceptibles en la composición y/o en la estructura del producto resulta complicado predecir cómo van a afectar dichos cambios a la aceptabilidad por parte del consumidor ya que dicha relación no es siempre directa. No todas las diferencias en composición, estructura o propiedades físicas del alimento dan lugar a diferencias perceptibles sensorialmente ni todas las diferencias sensoriales percibidas provocan cambios en la aceptabilidad por parte del consumidor (Mela, 2001). Es necesario, por tanto, en primer lugar entender la relación entre los cambios producidos en las propiedades físicas y químicas del producto y las diferencias percibidas sensorialmente. El análisis descriptivo cuantitativo (QDA®) es la técnica más extendida para describir y cuantificar las variaciones en las propiedades sensoriales de alimentos. La evaluación se lleva a cabo por un panel de catadores expertos o entrenados y, en general, se utilizan términos complejos y específicos para designar los atributos sensoriales. No obstante, la información obtenida, aunque precisa y detallada, puede estar alejada de las diferencias percibidas por los consumidores en una situación real de consumo. La evaluación de las características sensoriales directamente por los consumidores presenta ciertos problemas como la variabilidad en el uso de la escala y en la interpretación del vocabulario. En los últimos años se ha visto que existen técnicas alternativas que permiten la evaluación directa de las diferencias percibidas por los consumidores evitando dichos problemas. Así, las técnicas de comparación pareada, ordenación y el uso de las escala de adecuación (“Just About Right”) facilitan la tarea de evaluación de diferencias entre muestras por el consumidor. Mientras que las técnicas como el perfil de libre elección (“Free Choice Profile”), marque todo lo que corresponda (“Check All That Apply” o CATA) y la técnica “Sorting”, también hacen más fácil la evaluación del consumidor ya que puede utilizar su propio vocabulario.

La utilización del método de descripción entrecruzada (“Repertory Grid”) junto con el del perfil de libre elección permite obtener información directa sobre las sensaciones que los consumidores perciben al consumir un alimento y su intensidad (Jahan, paterson y Piggot, 2005; Jaeger, Rossiter y Lau, 2005; Hersleth, Mevik, Næs y Guinard, 2003) Los consumidores generan vocabulario fácilmente entendible aunque, dicho vocabulario, resulta demasiado personal o propio para que pueda ser interpretado por otra persona que no sea el propio consumidor (Piggott, Sheen y Apostolidou, 1990). El método “Repertory Grid” permite obtener para cada consumidor su propia lista de términos o atributos para describir un conjunto de muestras. El uso del perfil de libre elección permite, al igual que los perfiles convencionales, describir y cuantificar las diferencias entre muestras, sin embargo, difiere en cada individuo utiliza su propia lista de términos o atributos para evaluar las muestras en lugar de usar una única hoja de cata común para todos (Oreskovich, Klein y Sutherland, 1991). En el caso de que haya dimensiones comunes de percepción para un conjunto de consumidores, esto se traduciría en similitudes geométricas en los espacios matemáticos para el conjunto de datos obtenido de cada individuo.

Otra técnica que permite de una manera más sencilla obtener información sobre las características sensoriales de un producto percibidas por los consumidores es la utilización de las preguntas “marque todo lo que corresponda” (CATA). En una pregunta CATA los consumidores han de marcar las opciones que ellos consideren que describen mejor el producto de una lista de palabras o expresiones. La mayor dificultad de esta técnica radica en la elección de los términos o atributos que se les van a presentar a los consumidores ya que es necesario asegurarse de que todos ellos representen todas las posibles sensaciones que puedan ser percibidas por los consumidores. Es por ello que resulta interesante obtener esta lista de atributos mediante el “Repertory Grid Method” ya que de esta manera son ellos mismos los que van a generar los términos que describen las sensaciones percibidas durante el consumo del producto. Las preguntas CATA se han utilizado con diferentes objetivos. En un estudio realizado por Ares, Barreiro, Deliza, Giménez y Gámbaro (2010) se vio que, en general, los resultados obtenidos mediante las preguntas CATA y mediante QDA® fueron muy similares, indicando que las características sensoriales del producto (en esta caso, postres lácteos de chocolate) fueron evaluadas de la misma forma por los consumidores y por los catadores entrenados del panel. Del mismo modo, en un estudio llevado a cabo por Dooley, lee y Meullenet (2010) también se concluyó que los datos obtenidos mediante análisis descriptivo (en este caso Spectrum™) para la caracterización de helados de vainilla comerciales coincidieron en gran medida con los resultados obtenidos mediante las preguntas CATA.

La información acerca de las diferencias en intensidad de los atributos sensoriales que pueda percibir un panel de catadores entrenados o un grupo de consumidores puede ser útil también para entender las diferencias en aceptabilidad. El estudio de las relaciones entre las diferencias sensoriales percibidas en un producto y su aceptabilidad permiten identificar cuáles son los atributos que determinan la aceptabilidad o rechazo del producto y se conocen como “drivers of liking or disliking”.

Es importante tener en cuenta que la aceptabilidad final del producto no sólo depende de las sensaciones o satisfacción que pueda experimentar el consumidor al ingerir dicho producto, sino también de si el alimento responde a las necesidades del consumidor (Heldman, 2004). Así, además de las características sensoriales percibidas, es importante identificar las otras características (principalmente etiqueta, precio y conveniencia) que interesan a los consumidores y que pueden influir en la aceptabilidad final del producto. La opinión que cada consumidor tenga sobre las características nutritivas o la composición del producto (Bruhn at al., 1992), sobre la seguridad del mismo (Wilcock, Pun, Khanona y Aung, 2004), sobre su marca comercial (Varela, Ares, Giménez y Gámbaro, 2010) o su precio (Caporale y Monteleone, 2001; di Monaco, Ollila y Tuorila, 2005) condicionan su elección en el momento de la compra y puede incluso llegar a modificar la aceptabilidad final en el momento del consumo.

En el caso de productos con contenido reducido de grasa o en aquellos en los que se ha introducido una mejora nutricional, no sólo es importante evaluar o conocer la aceptabilidad sino que, además, es importante conocer cómo perciben los consumidores la información nutricional. Estudios previos indican que, en general, los consumidores consideran que se produce una reducción en la calidad del sabor del producto cuando el contenido de grasa disminuye aunque este efecto depende del producto considerado (Lloyd, Paisley y Mela, 1995; Norton, Fryer y Parkinson, 2013). Además de obtener información acerca de cómo entienden o interpretan los consumidores la información relativa al contenido o procedencia de la grasa, es importante evaluar su repercusión en las expectativas que tiene del producto y en su aceptabilidad final. Según Tuorila, Cardello y Leisher (1994), las expectativas hedónicas de los alimentos reducidos en grasa son generalmente más bajas que la de los productos con contenido normal de grasa y, normalmente, dichas expectativas se rigen por la familiaridad que tenga el individuo con el producto así como por sus hábitos dietéticos. Por otro lado, se ha observado que para un consumidor interesado en la salud, si el producto le proporciona un beneficio para la salud, su aceptabilidad para ese producto puede llegar a aumentar o, aunque la aceptabilidad no se vea afectada, la intención de compra puede aumentar (Ares, Giménez y Gámbaro, 2008). Por ello, tanto la respuesta hedónica como el comportamiento del consumidor o la combinación de ambos pueden verse afectados por la combinación de mensajes relacionados con la salud y de experiencias sensoriales (Kähkönen, Tuorila y Rita, 1996; Tuorila, Andersson, Martikainen y Salovaara, 1998).

El método de las expectativas es un enfoque realista en el que se tiene en cuenta cuánto le gusta el producto al consumidor, así como la idea preconcebida que tiene acerca de las diferentes características del producto y de sus características sensoriales (Torres-Moreno, Tárrega, Torrescana y Blanch, 2012). Normalmente, antes de probar un producto en particular, los consumidores suelen tener una idea de cómo van a ser las características sensoriales de este producto (expectativas sensoriales) y de cuánto les va a gustar o disgustar (expectativas hedónicas). Por lo tanto, las expectativas que se tienen acerca de un producto se pueden definir como la opinión previa que tienen acerca del mismo (Olson y Dover, 1979, Villegas, Carbonell y Costell, 2008; Torres-Moreno et al., 2012). Los consumidores generan estas expectativas en base a su experiencia previa con el producto o en base a su opinión acerca de las características del envase, las características nutricionales o de la composición del producto (Varela, et al., 2010; Bruhn et al., 1992).

Sin embargo, no existe mucha información acerca de cómo se percibe la información específica acerca de la fuente de la grasa o del perfil de ácidos grasos del producto. En un estudio llevado a cabo en EEUU, se vio que, aunque los consumidores están cada vez más concienciados sobre los efectos de la grasa en la dieta, el conocimiento que tienen sobre la fuente o procedencia de las grasas saturadas o de las grasas trans es relativamente bajo entre los consumidores de este país (Eckel et al., 2009). En el caso de las galletas, no se ha encontrado información acerca de cómo los consumidores perciben la reducción de grasa o una mejora del perfil de ácidos grasos. En un producto elaborado con aceites vegetales en lugar de la grasa convencional rica en ácidos grasos saturados, la información relativa a la mejora nutricional mostrada en la etiqueta puede indicarse de diferentes formas. Así, dicha etiqueta puede incluir una alegación que indique que el producto está hecho "con aceite de oliva" o "con aceite de girasol". Por otro lado, en la tabla de composición nutricional, se podría indicar el mayor contenido en los ácidos grasos monoinsaturados y poliinsaturados en detrimento de los ácidos grasos saturados. Además, cuando en el producto el total de ácidos grasos saturados y de ácidos grasos trans no supera los 1,5 g por 100 gramos de producto y, si estos ácidos grasos aportan menos del 10% de la energía total, en la etiqueta se puede indicar la alegación “bajo en grasas saturadas” (Regulation EC No 1924/2006). Por todo lo expuesto, el éxito de estos productos estará determinado por cómo perciban y entiendan los consumidores este tipo de información y por las expectativas que pueda crear dicha información en el consumidor.

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OBJETIVOS

El objetivo general de la presente tesis doctoral fue estudiar la viabilidad de un sistema aceite/gel de hidrocoloide empleado como sustituto de la grasa convencional utilizada en galletas para desarrollar un producto con un perfil de ácidos grasos más saludable. En este contexto se desarrollaron los siguientes objetivos parciales:

- Estudiar los cambios ocurridos en la textura de las galletas y en la aceptabilidad al sustituir la grasa convencional por sistemas aceite de girasol/gel formulados con distintos éteres de celulosa.

- Evaluar los cambios en las propiedades reológicas de la masa al sustituir la grasa convencional por los distintos sistemas aceite de girasol/gel formulados con distintos éteres de celulosa.

- Describir los cambios en las propiedades mecánicas y acústicas y los cambios sensoriales percibidos por los consumidores en galletas al sustituir la grasa convencional por sistemas aceite/gel de hidrocoloide con distinto tipo de aceite (girasol u oliva) y distinto tipo de hidrocoloide (hidroxipropilmetilcelulosa y goma xantana).

- Estudiar los cambios en la aceptabilidad de las galletas y las propiedades sensoriales responsables de los mismos al sustituir la grasa convencional por sistemas aceite/gel de hidrocoloide con distinto tipo de aceite (girasol u oliva) e hidroxipropilmetilcelulosa como hidrocoloide.

- Evaluar las expectativas de los consumidores creadas por la información nutricional de la etiqueta y su efecto en la aceptabilidad.

PRESENTACIÓN DE LOS TRABAJOS

El contenido de esta tesis doctoral se divide en seis capítulos que corresponden a los siguientes artículos publicados o en proceso de publicación en revistas científicas y que responden a los objetivos planteados.

CAPÍTULO 1

P. Tarancón, A. Salvador y T. Sanz. Sunflower oil - water – cellulose ether emulsions as trans fatty acid free fat replacers in biscuits. Texture and acceptability study. *Food and Bioprocess Technology,* DOI 10.1007/s11947-012-0878-6.

CAPÍTULO 2

P. Tarancón, M. J. Hernández, A. Salvador y T. Sanz. Relevance of creep and oscillatory tests to understand the functionality of cellulose emulsions as fat replacers in biscuits. Enviado a: *Food Hydrocolloid.*

CAPÍTULO 3

P. Tarancón, S. M. Fizman, A. Salvador y A. Tárrega. (2013). Formulating biscuits with healthier fats. Consumer profiling of textural and flavour sensations during consumption. *Food Research International,* 53: 134-140.

CAPÍTULO 4

P. Tarancón, T. Sanz, A. Salvador, A. Tárrega. Effect of fat on mechanical and acoustical properties of biscuits related to texture properties perceived by consumers. Aceptado para publicación: *Food and Bioprocess Technology.*

CAPÍTULO 5

P. Tarancón, A. Salvador, T. Sanz, S.M. Fiszman y A. Tárrega. Sensory properties and acceptance of biscuits made with olive and sunflower oil. Enviado a: *Food and Bioprocess Technology.*

CAPÍTULO 6

P. Tarancón, T. Sanz, S.M. Fiszman y A. Tárrega. Consumers' hedonic expectation and perception of the healthiness of biscuits made with olive or sunflower oil. Enviado a: *Food Research International.*

La primera parte de la tesis consistió en un estudio exploratorio para evaluar el efecto del reemplazo de grasa convencional por sistemas de aceite de girasol y distintos éteres de celulosa. Se evaluó la textura y aceptabilidad de galletas horneadas, así como los cambios producidos en las propiedades reológicas de la masa de galleta debidos a dicha sustitución (capítulos 1 y 2). En la parte central de la tesis, además del uso de aceite de girasol y de hidroxipropilmetilcelulosa como hidrocoloide, se propusieron nuevas alternativas para la elaboración de los sistemas aceite/gel como el uso de aceite de oliva, de goma xantana como hidrocoloide y una reducción menor del contenido de grasa (capítulos 3 y 4). Se describieron los cambios en las propiedades sensoriales de las galletas percibidas por los consumidores al variar el tipo y la cantidad de grasa y su relación con las propiedades mecánicas y acústicas. La última parte de la tesis se dedicó a evaluar la aceptabilidad de las galletas elaboradas con los sistemas de hidroxipropilmetilcelulosa y aceite de oliva o de girasol por parte de los consumidores (capítulos 5 y 6). Se estudió el efecto de las propiedades sensoriales en la aceptabilidad de las galletas así como el efecto de la información nutricional relativa a la fuente y contenido de grasa de la etiqueta.

CAPÍTULO 1

Sunflower oil - water – cellulose ether emulsions as trans fatty acid free fat replacers in biscuits. Texture and acceptability study

Food and Bioprocess Technology, Doi: 10.1007/s11947-012-0878-6.

SUNFLOWER OIL - WATER – CELLULOSE ETHER EMULSIONS AS TRANS FATTY ACID FREE FAT REPLACERS IN BISCUITS. TEXTURE AND ACCEPTABILITY STUDY

P. Tarancón, A. Salvador, T. Sanz

ABSTRACT

A new vegetable, and trans fatty acid free, fat replacer consisting of a sunflower oil - water - cellulose ether emulsion was employed to replace 100% of the shortening in a short dough biscuit recipe and the dough and biscuit texture properties were evaluated. In comparison to the shortening dough, the cellulose emulsion dough was significantly ($p<0.05$) softer and more elastic. However, the cellulose emulsion biscuits had higher spreadability, implying that the increase in dough elasticity was not affecting this property, probably because of the decrease in dough hardness. Although the cellulose emulsion biscuits contained 33% total less fat than the shortening biscuits, their instrumental texture properties were very similar, implying that the cellulose emulsion avoids the increase in hardness associated with fat reduction. This was associated with the thermal gelation ability of the cellulose ethers, which develops during baking. The overall consumer acceptance was significantly ($p<0.05$) higher in the shortening biscuits, but their scores were very similar to those of the cellulose emulsion biscuits (maximum difference 1.1/9 points).

Keywords: shortening replacer, cellulose ether, biscuit, texture, trans free

INTRODUCTION

High fat consumption, particularly of trans-saturated fatty acids, is associated with the development of various metabolic disorders such as obesity and type 2 diabetes, which, in turn, increase the risk of cardiovascular diseases and some types of cancer (Micha and Mozaffarian, 2010).

Biscuits are cereal-based products with high fat and sugar contents and a low water content (Chevallier et al., 2000). The functions of fat in this type of product are to improve the texture, appearance, lubricity, mouthfeel and flavour, contributing to their palatability (Drewnowski, 1992; Grigelmo-Miguel et al.,2001; Zoulias et al., 2002). Fat also adds bulk, retains water, facilitates heat transfer mechanisms at high temperatures (Drewnowski et al., 1998) and increases the feeling of satiety while eating (Leland, 1997). Additionally, fats are carriers for liposoluble aromatic molecules, so they act as aroma and flavour precursors and stabilize flavours.

The fats used in biscuit manufacture need to be solid or semi-solid at ambient temperature, which implies a high saturated fatty acid (SFA) content. Preparing biscuit doughs with liquid fats at ambient temperature is not feasible, as the dough becomes too smooth and soft, making it difficult to handle (Baltsavias et al., 1999). The most commonly used fats, in biscuit manufacture, are of animal origin, such as butter, or vegetable fats such as hydrogenated vegetable oils. Both these types of fat not only contain a high percentage of SFAs but also contain trans fatty acids.

Reducing the fat content of biscuits and, if possible, improving the quality of the fat employed would provide healthier alternatives. Owing to the important role of fats in this type of product, obtaining low-fat biscuits that are acceptable both technologically (dough handling) and from a sensory point of view (Zoulias et al., 2000; Sabanis and Tsia, 2009) is a complex task complicated. In the raw doughs, partially reducing the fat and replacing it with other compounds gives rise to considerable changes in their rheological properties, consistency, adhesiveness and ease of sheeting and cutting, as well as in their ability to hold their shape during baking. In the baked biscuits, a lower fat content has very negative effects on texture, principally causing greater hardness, which is associated with a loss of lubricating effect and greater development on the gluten network.

The effect of partial replacement of fat by different fat replacers on the quality of biscuits has been studied by different authors. Zoulias et al. (2002) compared the effect of different fat replacers on sugar free cookie properties. Replacing 35% of the fat with polydextrose resulted in very hard and brittle products. Further fat replacement, to 50%, was achieved using maltodextrin, inulin or a blend of microparticulate whey proteins and emulsifiers; however, the final products were hard, brittle and did not expand properly after baking. Replacing part of the fat with inulin gave rise to changes in physical properties, such as increased diameter after baking, higher moisture content and water activity (a_w) and greater biscuit hardness and brittleness. In general, the cookies with maltodextrin were rated as the most acceptable by a sensory panel. Replacing 50% of the fat with soluble β-glucan and amylodextrins derived from oat flour produced cookies that were not perceived as different from full-fat ones. At higher substitution levels, moistness and overall quality decreased (Inglett, Warner and Newman, 1994). The crispiness of biscuits decreased with increased fat substitution by pectin-based replacers (a blend of gums) or oats. These fat substitutes used produced a significant ($p<0.05$) increase in moisture content. Variations in volume and crumb firmness were associated with the type of fat substitute and the level of fat replaced (Conforti et al., 1996). The use of maltodextrins increased dough consistency, a_w, moisture and hardness (Forker et al., 2011).

Methylcellulose (MC) and hydroxypropyl methylcellulose (HPMC) are hydrocolloids which are obtained by etherifying cellulose and have the ability to gel on heating. The gel-formation temperature and the properties of the resulting gel depend on the type and degree of cellulose substitution, the molecular weight, the concentration and the presence of additives (Sarkar, 1979). MC and HPMC present good emulsifying properties and can be used to obtain stable emulsions of vegetable oil in water.

The aim of this study was to replace 100% of the shortening in a biscuit formulation with a fat replacer consisting of a cellulose ether -sunflower oil - water emulsion and assess the effects on the dough texture, on the baked biscuit, and on consumer acceptance. This sunflower oil – water – cellulose emulsion is a fat substitute that is free of trans fatty acids and has a significantly ($p<0.05$) lower level of saturated fatty acids than conventional shortenings. The effect of the degree of methoxyl and hydroxypropyl methyl substitution on the properties studied was also measured.

MATERIAL AND METHODS

Shortening replacer preparation

An oil-water-cellulose ether emulsion (oil in water) was used as the shortening replacer. Four different cellulose ethers with thermogelling ability supplied by The Dow Chemical Co. were employed. Their levels of methoxyl and hydroxypropyl substitution are shown in Table 1. The viscosity of the cellulose ethers was 4000 mPa s (2% aqueous solution at 20ºC measured by The Dow Chemical Company following reference methods ASTM D1347 and ASTM D2363).

Table 1. Levels of methoxyl and hydroxypropyl substitution of the different cellulose ethers

Commercial name	Type of cellulose	% methoxyl	% hydroxypropyl
MC A	methylcellulose	30.0	0.0
HPMC E	hydroxypropyl methylcellulose	29.1	9.1
HPMC F	hydroxypropyl methylcellulose	29.0	6.8
HPMC K	hydroxypropyl methylcellulose	22.5	7.7

Sunflower oil (Coosol), water and the different cellulose ethers were used to prepare 184 g of emulsion, employing the following proportions: 52.17%, 45.65% and 2.17% respectively. The cellulose ether was first dispersed in the oil using a Heidolph stirrer at the lowest speed for one minute. The mixture was then hydrated by gradually adding the water while continuing to stir. The water temperature was 10 ºC for all the HPMCs and 8º C for the MC. Stirring continued until the emulsion was obtained. The differences in the water temperature employed between HPMCs and MC was attributed to their different hydration temperature according to the specifications given by the manufacturer.

Biscuit ingredients

The ingredients used to produce the biscuits were (flour weight basis): soft wheat flour 100% (Belenguer, S.A., Valencia) (composition data provided by the supplier: 11% protein, 0.6% ash; alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), fat source 32.15%: shortening (St. Auvent, Diexpa, Valencia) (total fat: 78.4%, saturated fatty acids: 51%, monounsaturated fatty acids: 20%, polyunsaturated fatty acids: 6%, trans fatty acids< 2%) or shortening replacer, sugar 29.45% (Azucarera Ebro, Madrid, Spain), milk powder 1.75% (Central Lechera Asturiana, Peñasanta, Spain), salt 1.05%, sodium bicarbonate 0.35% (A. Martínez, Cheste, Spain), ammonium hydrogen carbonate 0.2% (Panreac Quimica, Barcelona, Spain) and tap water 9%. In the formulations with a shortening replacer, glycerol (3.2%) (Panreac Quimica, Barcelona, Spain) was also added to control the a_w.

Biscuit preparation

The shortening or shortening replacer, sugar, milk powder, leaving agents, salt, water and glycerol (in the case of biscuits made with the shortening replacer) were mixed in a mixer (Kenwood Ltd., U.K) for 1 minute at low speed (60 rpm), the bowl was scraped down and they were mixed again for 3 minutes at a higher speed (255 rpm). The flour was added and mixed in for 20 seconds at 60 rpm, then mixed for a further 40 seconds at 60 rpm after scraping down the bowl once more. The dough was sheeted with a sheeting machine (Parber, Vizcaya, España) and moulded to 64 mm diameter x 3.4 mm thick. Twenty biscuits were placed on a perforated tray and baked in a conventional oven (De Dietrich, France) for 6 minutes at 200 ºC. The trays were then turned 180ºC, bringing the side that had been at the back to the front of the oven to ensure homogenous baking, and baked for a further 6 min at the same temperature. The oven and the oven trays were always the same, the trays were placed at the same level in the oven and the number of biscuits baked was always the same. After cooling, the biscuits were packed and stored in heat-sealed metalized polypropylene bags. The biscuit samples were evaluated on the following day in all cases.

Dough texture measurements

Different texture tests were conducted to ascertain the properties of the dough. The sheeted dough (10 mm thick) from the different formulations was analysed.

A TA-XT.plus Texture Analyzer equipped with the Texture Exponent software (version 2.0.7.0. Stable Microsystems, Godalming, UK) was used. Three different types of tests were performed: wire cutting, sphere penetration and double compression. The test speed was always 1 $mm.s^{-1}$ and the trigger force was 5g in the wire cutting and sphere penetration tests and 10g in the double compression test. Each test was conducted on six replicates of each formulation.

Wire cutting measurements

Disks of dough with a 10 mm thick and a diameter of 64 mm were sheared transversally through the middle with a wire cutter. The area under the force/displacement curve was calculated and considered an index of dough hardness.

Double compression test (Texture Profile Analysis)

Dough disks of 10 mm thick with a diameter of 50 mm were compressed to 30% of their initial height using a 75 mm-diameter aluminium plate (P/75) with a 5-s waiting time between the two cycles. The parameters obtained from the curves were hardness (the peak force during the first compression cycle), springiness (the height that the food recovered between the end of the first compression and the start of the second compression) and cohesiveness (the ratio of the positive force area during the second compression to the positive force area during the first compression).

Biscuit evaluation

Dimensions

The biscuit diameter was measured by arranging ten biscuits along the length ruler and recording the average diameter. The biscuit thickness was measured by stacking 10 biscuits. The measurements were expressed in cm as the mean value/10 of four different trials.

Moisture content and water activity (a_w)

The moisture content of the biscuits was determined in three replicates of each formulation according to a modification of Approved Method 44-15A (AACC International, 2009). 5 g of samples were put in an oven at 105ºC until they reached a constant weight.

Water activity (a_w) was determined in three replicates of each formulation using a Decagon AquaLab meter (Pullman, WA, USA) calibrated with a saturated potassium acetate solution (a_w=0.22).

Texture analysis

The texture of the biscuits was measured using the same Texture Analyzer described before. A test speed of 1 mm.s^{-1} was used for all tests. Ten replicates of each formulation were conducted. Two different tests were performed: a three point break test and a bite test.

Three point break test

The biscuits were broken with the three point bending rig probe (A/3PB). The experimental conditions were: supports 50 mm apart, a 5 mm probe travel distance and a trigger force of 20g. The force at break (N) (breaking strength) was measured.

Bite test

The penetration tests were conducted with the upper Volodkevich Bite Jaw (VB), penetrating the sample (half biscuit) to 2 mm; a trigger force of 20 g was set. The maximum force at penetration (N) was measured.

Consumer sensory analysis

A total of 100 untrained panellists (consumers) aged from 15 to 64 years, who frequently consumed this type of biscuit, took part in the study. Each consumer received five biscuits (the control and one for each shortening replacer), presented individually in a single session following a balanced complete block experimental design. The biscuits were coded with random three-digit numbers. Consumer acceptance testing was carried out using a categoric nine point hedonic scale (9= like extremely; and 1= dislike extremely). The consumers had to score first their liking for the ‘appearance’ and ‘colour’, and after eating the sample their liking for ‘texture’, ‘flavour’, ‘sweetness’ and ‘overall liking’ for each biscuit sample.

Statistical analysis

Analysis of variance (one way-ANOVA) was applied to study the differences between formulations; least significant ($p<0.05$) differences were calculated by the Tukey test and the significance at $p < 0.05$ was determined. These analyses were performed using SPSS for Windows Version 12 (SPSS Inc., USA).

RESULTS AND DISCUSSION

Dough characteristics

Rheological (texture) properties are a consequence of the dough's internal structure and determine the processability and quality of the biscuits (Piteira et al., 2006). The consistency, elasticity and cohesiveness of the dough should be appropriate to guarantee adequate processing and final texture. The dough structure and properties are determined by the composition and proportion of the ingredients; fat is a crucial structural component. Different texture tests were carried out to evaluate the effect of shortening replacement by the different oil-water-cellulose emulsions on the dough texture.

Wire cutting test

This test consists in pushing a wire through the sample from an initial indentation to a steady-state cutting stage. The wire cutter has the advantage of presenting a constant contact area with the sample, minimizing the friction effects (Dunn et al., 2007). The test was conducted to measure the resistance of the dough when sliced through by a wire cutter. The relation between force and displacement in a wire cutting test depends on a combination of fracture, plastic/viscous deformation and surface friction effects (Laguna et al., 2011). The force/displacement curves for the different doughs are shown in Figure 1.

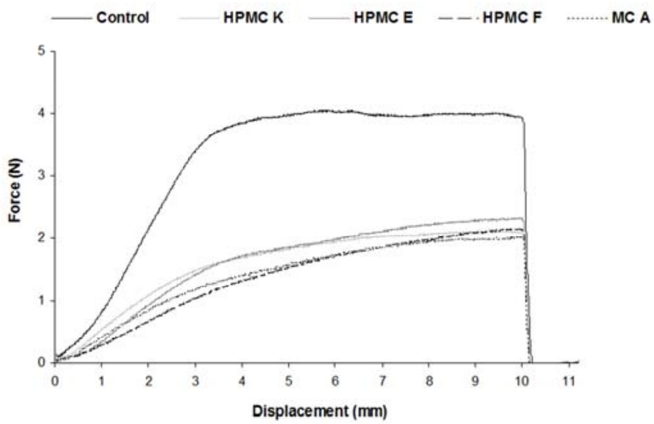

Figure 1. Wire cutting representative curves profiles of the control and fat replaced biscuit doughs.

This curves shown two different parts: a first part in which the force increased over time, corresponding to the initial indentation of the sample by the wire, and a second part in which the cut reached a steady state and the curve formed a plateau (Goh et al., 2005). As can be observed, the shortening dough (control) presented higher force values than those prepared with the oil-water-cellulose emulsions. Slope of the initial portion of the rise in the curve indicates the rigidity of the samples whereas the area behind the curve can be associated with the shearing work and thus can be related to biscuit hardness. The slope of the first part of the control dough curve was also steeper, indicating that greater force was required for the initial cut in this dough.

The area under the curve (AUC) values from the cutting tests on the different doughs are shown in Table 2. As with the curve profiles, the control dough prepared with shortening presented a significantly ($p<0.05$) higher AUC than the doughs with cellulose, indicating that greater force was needed to cut it. No significant ($p>0.05$) differences were found between the doughs prepared with the different cellulose ethers. Consequently, replacing the shortening with the oil-water-cellulose emulsions produced doughs with less resistance to cutting, reducing the work needed to cut the samples.

Table 2. Dough texture characteristics for the control and the different cellulose emulsion formulas.

Dough sample	**Wire cutting**	**TPA**		
	AUC (N·mm)	Hardness (N)	Springiness	Cohesiveness
Control	37.95a (5.79)	128.9b (25.8)	0.36a (0.03)	0.24a (0.01)
HPMC K	15.78b (0.93)	42.6a (8.8)	0.53b (0.10)	0.38bc (0.06)
HPMC E	15.29b (1.66)	30.6a (6.2)	0.67b (0.13)	0.44c (0.05)
HPMC F	13.40b (0.63)	31.6a (7.0)	0.51ab (0.22)	0.35b (0.09)
MC A	13.26b (1.21)	36.6a (3.3)	0.58b (0.15)	0.35b (0.05)

Values in parentheses are standard deviations.
Means in the same column with the same letter do not differ significantly ($p < 0.05$) according to the Tukey's test.
AUC: area under force/time curve

Double compression test (Texture Profile Analysis)

The curves obtained in the double compression test are shown in Figure 2.

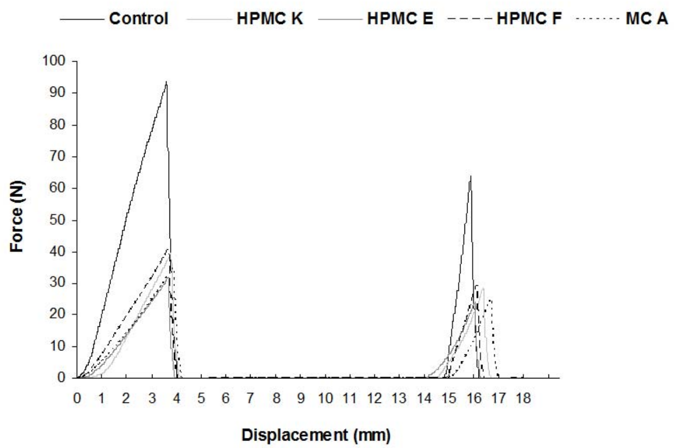

Figure 2. Double compression representative curves profiles of the control and fat replaced biscuit doughs.

As in the previous tests, the doughs prepared with the different cellulose ether emulsions presented a group of similarly-shaped curves while that of the dough with shortening was different from the rest. Equally, the shortening dough was again found to be harder than those prepared with the cellulose ether emulsions and no significant ($p>0.05$) differences were found between these (Table 2). The lower dough hardness observed in all the texture tests when the shortening was replaced by the cellulose emulsions contrasts with the results of previous studies in which greater hardness was found when the fat content was reduced, whether or not a replacer was employed. The increased hardness described in the literature when biscuits were made with lower fat contents is associated with the ability of fat to lubricate, weaken or soften the structure of food components. Also, reducing the fat content of the dough implies that more water is necessary to yield a suitable consistency for dough piece forming. This extra water allows more flour protein hydration and more gluten formation, which results in a tougher dough. For example, Sudha et al. (2007) found an increase in dough hardness as the fat level decreased in soft dough biscuits. Employing maltodextrin and polydextrose as fat replacers reduced the dough consistency and dough hardness to some extent and further improvement in dough characteristics was possible with the addition of glycerol mono stearate and guar gum.

The reason why the doughs prepared with the trans fatty acid-free cellulose emulsions were less hard despite the significant reduction (33.13%) in the total fat content may be linked to the fact that the source of fat in the emulsion is a liquid vegetable oil, as the lubrication effect of fat has been associated with the liquid oil fraction in the shortening. The doughs prepared with the cellulose emulsions contained 33.13% less total fats but 100% of their fat was liquid oil. By coating the sugar and flour particles, the oil reduces the mixing time, reduces the energy required for mixing, and smoothens the dough (Pareyt and Delcour, 2008a). Also, the high water absorption rate of the cellulose ethers in the emulsion means that the greater part of the water in the formulation would not be totally available for hydrating the proteins, reducing the increased consistency associated with a more developed gluten network.

The texture profile analysis showed that the springiness and cohesiveness of all the doughs prepared with the cellulose ether emulsions (Table 2) were greater than in the shortening formulation and that the degree of methoxyl and hydroxypropyl substitution in the cellulose ethers did not significantly ($p>0.05$) affect the dough springiness.

Unlike the hardness results, the tendency for springiness and cohesiveness to rise when the fat content is reduced was expected from the functionality generally described for fats in biscuit doughs. However, the explanation for this effect cannot be associated with the same causes, or at least not if it is considered that the water did not bring about greater gluten network hydration in the cellulose emulsions because its priority use was to hydrate the cellulose ether. In general, the greater springiness of the dough when the fat content was reduced was associated with the fact that in the absence of shortening the water or sugar solution would interact with the flour protein to create cohesive and extensible gluten, which confers elasticity and cohesiveness. Hadnarev et al. (2011) stated that blends consisting of vegetable fat and different type, content and concentration of an aqueous maltodextrin gel had lower hardness than a vegetable shortening. In the case of the doughs with cellulose emulsions, the most likely cause of the increased springiness and cohesiveness has to be associated with the presence of the cellulose emulsions themselves rather than with their effect on the functionality of the other ingredients. Sudha et al. (2007) obtained higher elasticity, cohesiveness and adhesiveness values on reducing the fat content. From a technological point of view, an increase in the elasticity of a biscuit dough is not an advisable property (Sudha et al., 2007), as if the dough is too elastic, it will tend to recover its initial shape after sheeting, reducing the spread and affecting final dimension of the biscuit.

In short, total replacement of the shortening by the cellulose emulsions prepared in this study altered the rheological properties of the doughs significantly ($p<0.05$), causing them to become softer, more elastic and more cohesive. The type of cellulose ether substitution did not exert a significant ($p>0.05$) effect.

Biscuit evaluation

Dimensions

One decisive aspect of final biscuit quality is the expansion of the dough during baking, as this determines the size and texture of the biscuit (Seker et al., 2010). The diameter and thickness of the biscuits are shown in Table 3. Both the diameter and the thickness were significantly ($p<0.05$) greater in the biscuits formulated with the cellulose ether emulsions than in those formulated with shortening, without any significant ($p>0.05$) differences between the different types of cellulose ether.

Table 3. Physical and texture characteristics of biscuits for the control and the different cellulose emulsion formulas.

Biscuit sample	Length (cm)	Thickness (cm)	Moisture % (w/w)	a_w	3-point break test Max. force (N)	Penetration test Max. force (N)
Control	6.47a (0.07)	0.63a (0.03)	0.632a (0.221)	0.305a (0.005)	16.73a (2.48)	46.16ab (10.16)
HPMC K	6.79b (0.04)	0.74c (0.05)	2.218c (0.565)	0.317a (0.005)	16.56a (2.44)	39.10a (4.33)
HPMC E	6.71b (0.03)	0.70bc (0.01)	2.090bc (0.337)	0.282a (0.005)	15.63a (1.77)	48.54b (7.68)
HPMC F	6.72b (0.05)	0.72bc (0.03)	1.640b (0.187)	0.264[a] (0.005)	23.51b (3.47)	48.786b (12.89)
MC A	6.73b (0.04)	0.67ab (0.04)	2.163bc (0.164)	0.268a (0.005)	15.39a (2,16)	38.97a (7.22)

Values in parentheses are standard deviations.
Means in the same column with the same letter do not differ significantly ($p < 0.05$) according to the Tukey's test.

The fat content is a decisive factor for the final dimensions of the biscuit. The fat covers the proteins and starch granules, isolating them and interrupting the continuity of the structure formed by the protein and starch (Pareyt and Delcour, 2008b). In the presence of fat the dough is less elastic, which is an advantage in biscuit-making because it prevents the dough from shrinking after sheeting. As a result, reducing the fat content of biscuit formulations generally leads to lower biscuit spread, which has a negative effect on the final biscuit quality (Sudha et al., 2007). For instance, biscuits in which up to 50% of the fat was replaced by maltodextrin, inulin or a blend of microparticulate whey proteins and emulsifiers did not expand propertly after baking (Zoulias et al., 2002). The results of replacing the shortening with the cellulose ether emulsions showed that the tendency in the cellulose emulsion doughs differs from that which is found when fat is eliminated or is replaced by other substitutes, as the biscuits formulated with the cellulose ether fat replacer showed greater expansion during baking (greater final diameter and thickness).

Here again, the greater diameter of the biscuits made with cellulose ethers cannot be explained in terms of dough elasticity, as these doughs presented greater elasticity than the control dough. In this case, the greater expansion of the biscuits made with cellulose ethers may be explained by the lower hardness of these doughs, which would therefore be more fluid, giving dough with greater diameter during sheeting and baking.

Moisture content and water activity (a_w)

As expected, the biscuits prepared with the cellulose emulsions presented significant ($p<0.05$) higher moisture content than those with shortening (Table 3), owing to the higher percentage of water in the formulation of the former. Comparison among the different types of cellulose ether showed up a slight significant ($p<0.05$) difference between the HPMC F and HPMC K biscuits, being greater for HPMC K than for HPMC F.

However, despite the differences in moisture, the a_w values of the different biscuits did not differ significantly ($p>0.05$). This was because glycerol was added to the cellulose emulsion formulations to reduce the water activity. The a_w values fluctuated between 0.2 and 0.3, in other words, below the permitted limit after which microorganism growth takes place and enzymatic oxidation reactions appear (Labuza and Dugan, 1971).

Biscuit texture analysis

The mechanical properties of the biscuits have a direct effect on sensory perception and are related, therefore, to consumer acceptance of these products (Baltsavias et al., 1999). One of the main quality defects in biscuits that have a lower percentage of total fat, with or without the use of replacers, is increased fracture force, which implies increased hardness, distancing these biscuits from the typical hardness level of short-dough biscuits (Baltsavias et al., 1999; Forker et al., 2001).

The three-point break test measures the force required to break a biscuit in half. The force/ displacement curve profiles obtained in this test are presented in Figure 3. The texture profiles of all the biscuits were very similar. Comparison between the different types of cellulose ether showed that the biscuits containing the HPMC with the lowest percentage hydroxypropyl groups (HPMC F) registered the greatest break force compared to the other samples (Table 3), so this formulation was the hardest The greater hardness in samples with HPMC F may be explained by the lower moisture content in this sample (Table 3). The control biscuits did not exhibit significant ($p>0.05$) differences in maximum break force values from those of the biscuits containing MC and HPMC types K and E. Nor were significant ($p>0.05$) differences found between biscuits with a zero hydroxypropyl group content (MC A) and those with the highest hydroxypropyl substitution (HPMC K and E), so this substitution appears not to affect the break properties of the biscuits studied.

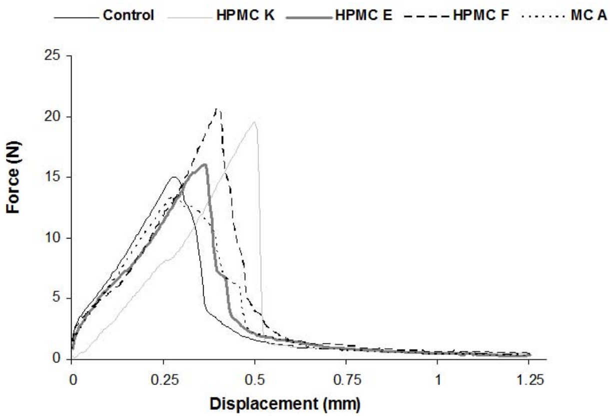

Figure 3. Three-point break representative curves profiles of the control and fat replaced biscuits.

The similarity between the texture curves of the biscuits with shortening and those with the cellulose emulsions is worth noting, as one of the main quality defects associated with fat reduction/replacement in biscuits is a considerable change in texture, mainly in the form of a very significant ($p<0.05$) increase in hardness.

The fat surrounds the proteins and the starch granules, isolating them and breaking the continuity of the protein and starch structure. This phenomenon results in eating properties after baking that are described as less hard, shorter and more inclined to melt in the mouth. Where the sugar level is high, the fat combines in the oven with the syrupy solution, preventing it from setting to a hard vitreous mass on cooling (Manley, 2000). Also, the decrease in the fat content of the dough needs to be compensated with more water to yield consistencies suitable for dough piece forming, and this extra water gives more flour protein hydration and more gluten formation, which in turn gives tougher dough and harder cookies (Manley, 2000).

The texture results obtained in the cellulose emulsion biscuits indicate that the cellulose emulsions simulate the functionally of the shortening quite effectively. In general, the fact that the biscuit hardness did not increase significantly ($p>0.05$) implies that gluten development is not greater than in the control biscuit. This confirms that although the water level in the emulsion biscuits is very high, this water is not readably available for protein hydration as can be seen in a_w values (Table 3) where no significant ($p>0.05$) differences were found among the cellulose and control biscuits.

Also, as in the case of the dough texture, the presence of the cellulose emulsion in itself exerts an effect on the biscuit texture, irrespective of its effect on the functionality of the other ingredients. MC and HPMC possess the property of thermogelling (Kobayashi et al.,1999 and Sanz et al., 2005). When the biscuit dough is baked, thermogelling causes a gel to form. It is probably the development of this gel-type texture during baking that is responsible for avoiding the hard texture normally found with fat reduction or replacement.

Figure 4 shows the results of the penetration test with the Volodkevich Bite Jaws, which imitate the force required to bite the biscuit (Laguna et al., 2011).

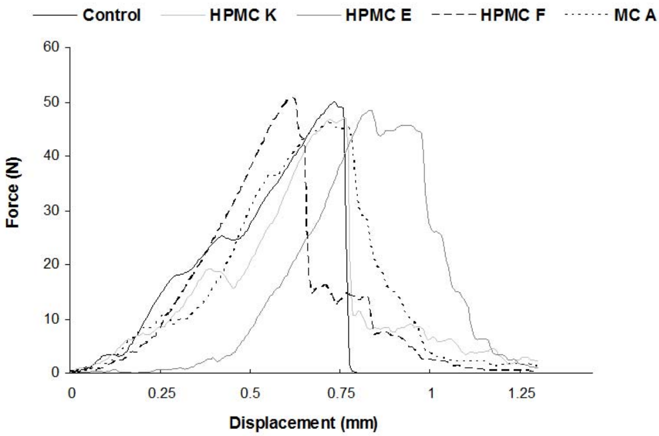

Figure 4. Penetration representative curves profiles of the control and fat replaced biscuits.

In general, the biscuits containing cellulose ethers did not present significant (p>0.05) differences in maximum penetration force compared to those made with shortening (Table 3). Also, the presence of methoxyl groups in the biscuits made with the different cellulose ethers did not affect their hardness, as no significant (p>0.05) differences were observed between the celluloses with the highest and lowest methoxyl group content (MC A and HPMC K respectively). The same was found for hydroxypropyl substitution: there was no significant (p>0.05) difference in hardness between the biscuits with zero and medium substitution levels (MC A and HPMC K respectively).

Consumer sensory analysis

The results for appearance, colour, texture, flavour, sweetness and overall liking for the different samples is shown in Figure 5.

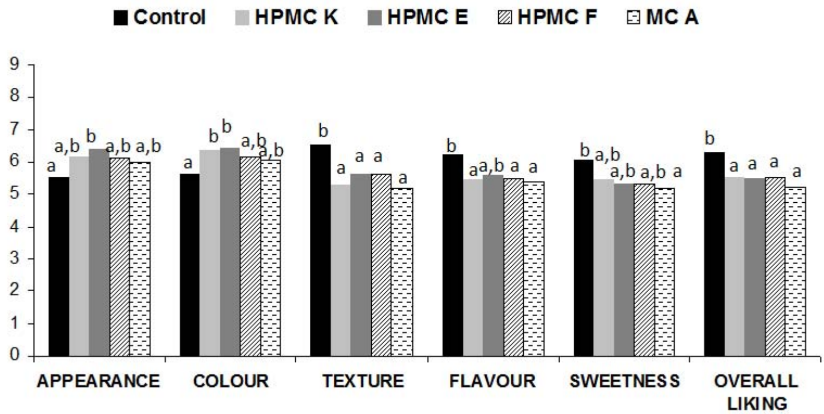

Figure 5. Scores for sensory hedonic test of biscuits. Scores not sharing letters were significantly different (p≤ 0.05) according to Tukey test.

The appearance of the biscuit with the greatest quantity of hydroxypropyl groups (HPMC E) was rated higher than that of the other samples with cellulose, although the difference was not significant ($p>0.05$). However, the liking for its appearance was significantly ($p<0.05$) higher than for the control. This formulation and the one with the next-highest quantity of hydroxypropyl groups (HPMC K) also scored significantly ($p<0.05$) higher on colour (6.44 and 6.34 respectively) than the control. Even though the sugar content was the same in all the samples, the biscuits made with the methylcellulose emulsion (MC A - no hydroxypropyl group) were rated considerably lower on sweetness than the sample containing shortening. This could be an indication that methylcellulose may influence some aspect related to the perception of sweetness. Owing to the decisive role of fats in texture and flavour development in this type of product, these and overall liking were the attributes most affected by replacing the shortening with the cellulose emulsions. The texture of the control biscuits achieved the highest score (6.51) by a significant ($p<0.05$) margin, but the mean scores of all the biscuits with cellulose ethers were always over 5, indicating that they were acceptable to the consumers. In terms of flavour, the control biscuits were rated the highest (6.22), although the differences compared to those prepared with the HPMC with the highest percentage of hydroxypropyl groups (HPMC E) were not significant ($p>0.05$), unlike the differences between the control biscuits and all the other samples. The overall liking scores for the different samples showed that the consumers preferred the control biscuits to any of the others. However, the differences were very small (the maximum difference was 1.1/9 points) and the scores for all the biscuits containing cellulose ethers were always over 5.2. The difference in overall acceptance could be related mainly to the difference in the texture scores and the absence of a buttery aroma, which is not present in the biscuits made with the cellulose emulsions. In principle, however, this aspect could be solved by adding butter aromas.

CONCLUSIONS

The cellulose emulsions can be considered a suitable trans fatty acid free fat replacer for shortening, which in addition reduced the final fat content of the biscuits by 33%. The cellulose emulsions significantly ($p<0.05$) alter the dough texture, which becomes softer, more elastic and cohesive than in a traditional dough recipe prepared with shortening. Despite biscuit dough being more elastic, the biscuit spreadability was higher in the cellulose emulsion doughs, which cannot be explained in terms of their elasticity properties but can be understand in relation to the greater softness of the dough due to the formation of a gel with the cellulose ethers. After baking, the texture of the cellulose emulsion biscuits was not significantly ($p>0.05$) different to that of the standard shortening biscuits, which reflects the suitability of the cellulose emulsion for replacing 100% of the shortening. The similarity in texture properties between the two types of biscuits, despite their different fat content, can be associated with the thermal gel formed by cellulose during baking, which simulates the softness in texture provided by fat. The degree of methoxyl and hydroxypropylmethyl substitution did not affect the dough or biscuit texture significantly ($p>0.05$). In general, acceptability of trans fatty acid free fat biscuits was only slightly lower than that of the control biscuits.

ACKNOWLEDGEMENTS

The authors are grateful to The Dow Chemical Co. for kindly supplying the cellulose ethers and to Mary Georgina Hardinge for assistance with the English-language manuscript.

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CAPÍTULO 2

Relevance of creep and oscillatory tests to understand the functionality of cellulose emulsions as fat replacers in biscuits

Enviado a la revista *Food Hydrocolloids*

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RELEVANCE OF CREEP AND OSCILLATORY TESTS TO UNDERSTAND THE FUNCTIONALITY OF CELLULOSE EMULSIONS AS FAT REPLACERS IN BISCUITS

Paula Tarancón, María J. Hernández, Ana Salvador, Teresa Sanz

ABSTRACT

Fat mostly employed in biscuit manufacturing contain a high percentage of saturated fatty acids, which confer a solid consistency necessary for biscuit manufacture. Due to health reasons the reduction of saturated fatty acids and trans fatty acids is desired. An emulsion composed of sunflower oil, water and a cellulose ether is employed in this work to completely replace the conventional fat of a short dough recipe. The effect of the methoxyl and hydroxypropyl content of the cellulose was also evaluated. The structure of the different doughs was measured by oscillatory and creep rheological tests and the results related to dough biscuit performance during baking. The compliance values during the creep test were adjusted successfully to the Burger model and doughs containing the cellulose emulsion presented lower resistance to deformation than control doughs. The oscillatory tests also reveal the existence of a more liquid like structure, with lower values of the elastic and loss modulus in the cellulose emulsion doughs. The level of methoxyl and hydroxypropyl of the cellulose ether did not exert a significant effect in the dough rheological properties. The obtained viscoelastic results (lower dough consistency and lower elasticity) explained the higher spreadness of the cellulose biscuits.

Key words: cellulose ethers, fat substitute, biscuit dough, oscillatory, creep, rheology

INTRODUCTION

The three main components of a biscuit recipe are flour, sugar, and fat. The functions of fat in biscuits are to improve the texture, appearance, lubricity, mouthfeel and flavour, contributing to their palatability (Drewnowski, 1992; Zoulias, Oreopoulou, & Kounalaki, 2002). Fat surrounds the proteins and the starch granules, isolating them and breaking the continuity of the protein and starch structure, thereby limiting the formation of a gluten network (Maache-Rezzoug, Bouvier, Allaf, & Patras, 1998; Ghotra, Dyal, & Narine, 2002). The produced dough has less elastic properties, which is desirable in cookie-making, since it does not shrink after lamination (Baltsavias, Jurgens, & van Vliet, 1997; Maache-Rezzoug et al., 1998).

The fat employed in biscuit manufacturing should have suitable plasticity properties (consistency and high melting temperature), allowing the air to be incorporated during dough formation and enabling the dough to withstand the high temperatures reached during baking and hold its shape for longer (Litwinenko, Rojas, Gerschenson, & Marangoni, 2002; Lee, Akoh, & Lee, 2008). The most frequent types of fat employed in biscuit manufacturing are vegetable fat and animal fat (butter), which contain a high percentage of saturated fatty acids, so they are not liquid at ambient temperature.

Consumers are concerned about the need to reduce the level of saturated fatty acids and trans fatty acids in the diet because of their relationship with health disorders such as obesity, cancer, high blood cholesterol and coronary heart disease (Akoh, 1998). However, due to the important functionality of fat in biscuits, a reduction in the level of fat or the replacement of the type of fat is a difficult task. Low fat biscuits showed problems in dough machinability and lift during baking mainly associated to higher gluten development (Manley, 2000). The reduction in fat content has also a very negative impact in biscuit texture, which becomes hard and tough.

A reduction of the level of saturated fatty acids and the elimination of trans fatty acids in biscuits can be accomplished by the employ of a sunflower oil–water–cellulose emulsion. The consistency provided by the cellulose emulsion makes possible the incorporation of liquid oil in the biscuit recipe. The biscuits obtained with the emulsion presented similar texture and consumer acceptability than the control, although containing 33% less fat and no trans fatty acids. The similarity in texture with the control was attributed to the thermal gelation properties of the cellulose ether (methylcellulose or hidroxipropilmethylcellulose) (Tarancón, Salvador, & Sanz, 2012). The texture properties of the doughs were analyzed by a wire cutting test and by a double compression test. The oil-water cellulose emulsion produced doughs with less resistance to cutting. Results from the double compression tests revealed that the cellulose emulsion doughs showed lower hardness and higher springiness and cohesiveness (Tarancón et al., 2012). The lower hardness in the cellulose emulsion dough could explain the higher biscuit dimensions achieved. However, it is difficult to understand the relationship among higher dough springiness and higher biscuit dimensions.

Apart from empirical measurements, such as texture measurements, dough rheological properties can be measured with fundamental tests. Oscillatory and creep–recovery are fundamental tests that measure the linear viscoelastic properties of a substance. The stress applied to the sample in the linear viscoelastic region is low enough not to produce an irreversible change in the structure, so information about the unaltered system structure is obtained. Zaidel, Chin, & Yusof, (2010) made a revision of the different fundamental tests employed to determine the rheological properties of doughs, which includes dynamic oscillation (Amemiya & Menjivar, 1992; Khatkar, Bell, & Schofield, 1995; Uthayakumaran, Newberry, Phan-Tien, & Tanner, 2002; Tronsmo, Magnus, Baardseth, & Schofield, 2003) and creep and recovery tests (Janssen, van Vliet, & Vereijken, 1996; Tronsmo et al., 2003). Fundamental rheological studies on biscuits doughs are scarce. Baltasavias et al. (1997) found that the type and amount of fat added to the dough has a strong effect on the viscoelastic properties. Pedersen, Kaack, Bergsøe, & Adler-Nissen, (2004) studied the rheological properties of biscuit dough from different cultivars and found that creep parameters and the phase angle were the parameters that better contribute to the explanation of the variability in biscuit length. Laguna, Hernández, Salvador, & Sanz, (2012) studied the effect of wheat flour replacement by resistant starch in biscuit dough linear viscoelastic properties. The increase in the level of resistant starch decreased dough deformability, which was associated to a decrease in biscuit spread during baking (Laguna et al., 2012).

The aim of the present work was to better characterize the differences in biscuit dough structure induced by the replacement of conventional fat by the sunflower oil cellulose emulsions by means of the study of the linear viscoelastic properties by oscillatory and creep tests. The relationship among the obtained rheological parameters and previously obtained dough texture parameters and biscuit dimensions and texture was also investigated.

MATERIAL AND METHODS

Materials

Dough ingredients were (flour weight basis): soft wheat flour 100% (Belenguer, S.A., Valencia) (composition data provided by the supplier: 11% protein, 0.6% ash; alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), shortening (St. Auvent, Diexpa, Valencia, Spain) (total fat: 78.4%, saturated fatty acids: 51%, monounsaturated fatty acids: 20%, polyunsaturated fatty acids: 6%, trans fatty acids< 2%) or shortening replacer 32.15%:, sugar 29.45% (Azucarera Ebro, Madrid, Spain), milk powder 1.75% (Central Lechera Asturiana, Peñasanta, Spain), salt 1.05%, sodium bicarbonate 0.35% (A. Martínez, Cheste, Spain), ammonium hydrogen 0.2% (Panreac Quimica, Barcelona, Spain) and tap water 9%. In the formulations with a shortening replacer, glycerol (3.2%) (Panreac Quimica, Barcelona, Spain) was also added to control the water activity.

An oil-water-cellulose ether emulsion was used as the shortening replacer. Four different cellulose ethers supplied by The Dow Chemical Co. with approximately the same viscosity (4000 mPas) (2 % aqueous solution at 20 °C measured by The Dow Chemical Company following reference methods ASTM D1347 and ASTM D2363) and thermogelling ability were employed. Their levels of methoxyl and hydroxypropyl substitution are shown in Table 1.

Table 1. Levels of methoxyl and hydroxypropyl substitution of the different cellulose ethers

Commercial name	Type of cellulose	% methoxyl	% hydroxypropyl
MC A	methylcellulose	30.0	0.0
HPMC E	hydroxypropyl methylcellulose	29.1	9.1
HPMC F	hydroxypropyl methylcellulose	29.0	6.8
HPMC K	hydroxypropyl methylcellulose	22.5	7.7

Sunflower oil (Coosol, Jaén, Spain), water and the different cellulose ethers were used to prepare 184 g of emulsion. The employed proportions were: sunflower oil (52.17%), cellulose ether (2.17%) and water (45.65%). The cellulose ether was first dispersed in the oil using a Heidolph stirrer at the lowest speed for one minute. The mixture was then hydrated by gradually adding the water while continuing to stir. The water temperature was 10 ºC for all the HPMCs and 8º C for the MC The difference in the water temperature employed between HPMCs and MC was attributed to their different hydration temperature, according to the specifications given by the manufacturer. Stirring continued until the emulsion was obtained.

Dough preparation

The shortening or shortening replacer, sugar, milk powder, leaving agents, salt, water and glycerol (in the case of biscuits made with the shortening replacer) were mixed in a mixer (Kenwood Ltd., UK) for 1 min at low speed (60 rpm), the bowl was scraped down and they were mixed again for 3 min at a higher speed (255 rpm). The flour was added and mixed in for 40 s at 60 rpm, then mixed for a further 20 s at 60 rpm after scraping down the bowl once more. The dough was sheeted with a sheeting machine (Parber, Vizcaya, España) and moulded to 64 mm diameter x 3.4 mm thick. It should be noted that every manipulation of dough induces some stress in the test-piece, so to ensure dough's stability, they were kept in a refrigerator for 24h before each test. Test-pieces were shaped by punching a tube of 23.3 mm internal diameter into the dough and cutting the cylinder obtained into pieces of pre-determined height by means of a wire.

Rheological experiments

Oscillatory and creep and recovery tests were performed at 25 ºC in a controlled stress rheometer (AR-G2, TA Instruments, Crawley, England) with the temperature controlled by a Peltier system. The rheometer was equipped with a 20 mm roughened parallel plate with a gap of 3.5 mm. Dough cylinders were placed on the rheometer. The samples were allowed to rest in the measurement position for a 10 min equilibration time. Each measurement was carried out 3 times in doughs prepared on different days. To protect against dehydration, vaseline oil (Panreac, Spain) was applied to the exposed surfaces of all the samples.

Oscillatory tests

Stress sweeps were carried out at a frequency of 1 Hz to determine the extension of linear viscoelastic response. A stress amplitude of 3 Pa was chosen in order to perform frequency sweeps from 10 to 0.01 Hz. Storage modulus (G'), loss modulus (G'') and loss tangent (tan δ = G''/G') values were recorded.

Creep tests

In a creep experiment, an instantaneous shear stress (σ_0) is applied in dough sample and the sample strain is recorded as a function of the creep time. The results are expressed as compliance J(t) [1/Pa], by the following formula: $J(t) = \gamma(t)/\sigma_0$. The shear stress applied during the creep phase was selected within the linear viscoelastic region (3 Pa) and maintained for 1200 s.

Statistical analysis

Analysis of variance (one way-ANOVA) was applied to study the differences between formulations; the least significant differences were calculated by the Tukey test and the significance at $p<0.05$ was determined.

A Principal Component Analysis (PCA) was used to correlate the creep and rheological parameters with dough texture properties. These analyses were performed using the statistical software XLSTAT, 2009.4.03 (Addinsoft, Barcelona, Spain).

RESULTS AND DISCUSSION

Creep tests

The values of compliance ($J= \gamma/\sigma$) as a function of time, J(t), for the different doughs are shown in Fig.1. The replacement of shortening by the cellulose emulsions clearly influenced the viscoelastic properties. The cellulose emulsion doughs showed higher values of compliance during the creep test, indicating a lower resistance to deformation than the control dough. A lower compliance values are indicative of a lower resistance to deformation and thus a weaker matrix structure. The lower resistance to deformation of the cellulose emulsion doughs is in accordance with the texture studies carried out by Tarancón et al. (in press), which found the cellulose emulsion dough to be less hard

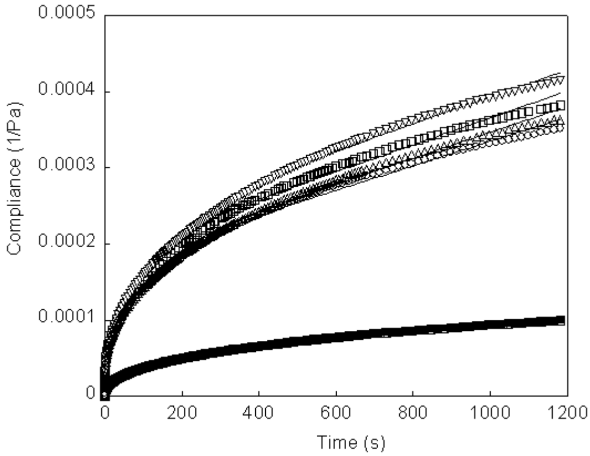

Figure 1. Compliance versus time in the creep test for the different formulations. ■ Control, □ HPMCE, △ HPMCF, ▽HPMCK, ○ MCA

The effect was associated to the employment of a liquid oil as a fat source, as the lubrication effect of fat has been associated with the liquid oil fraction in the shortening. By coating the sugar and flour particles, the oil reduces the mixing time, reduces the energy required for mixing and smoothens the dough. Also, the high water absorption rate of the cellulose ethers would have reduced the water available for hydrating the proteins, reducing the increased consistency associated with a more developed gluten network.

The creep data ($0 \leq t \leq 1200$ s) were satisfactorily adjusted to the Burger model (Eq. 1), always yielding values of $r \geq 0.996$. The Burger model is made up of four components that comprise the association in series of the Maxwell model and the Kelvin–Voigt model (Steffe 1996; Barnes 2000).

$$J(t) = \frac{1}{G_0} + \frac{1}{G_1}\left[1 - \exp\left(\frac{-G_1 t}{\eta_1}\right)\right] + \frac{t}{\eta_0} \quad (1)$$

J(t) represents the overall compliance at any time t, G_0 is the instantaneous elastic modulus of the Maxwell element and G_1 is the elastic modulus of the Kelvin–Voigt element. The dashpot of the Maxwell element represents the residual viscosity (η_0) and the dashpot associated with the Kelvin–Voigt element is the internal viscosity, η_1. These values allow comparing the internal structure of different systems, yielding a mechanical model with behaviour in response to deformation that is similar to that of such systems (Dolz, Hernández, & Delegido, 2008). The values obtained for G_0, η_0, G_1 and η_1 are shown in Table 2. A completely different pattern of behaviour was found between the control and the cellulose emulsion doughs. In comparison to the control dough, the cellulose emulsion doughs are characterized by lower values of G_0 and higher values of η_0. The values of G_0, instantaneous elastic modulus of the Maxwell unit, inform about the initial instantaneous deformation. Higher G_0 indicates a more elastic nature and higher recovery ability, as it corresponds to the initial instantaneous deformation. No significant differences in G_0 were found among the different cellulose emulsion. The lower G_0 values in the cellulose emulsion doughs would explain the greater diameter achieved in those biscuits, as higher instantaneous elasticity induces dough shrinking after lamination.

Table 2. Burger model parameters obtained from the creep data for the different dough samples.

Samples	Burger model parameters			
	G_0 x10^{-4} (Pa)	η_0 x 10^{-6} (Pa·s)	G_1 x 10^{-4} (Pa)	η_1 x 10^{-6} (Pa·s)
Control	7.63a (0.66)	2.1a (0.14)	2.92a (0.25)	3.56ab (0.46)
HPMCE	3.48b (0.36)	4.86b (0.07)	7.28b (0.30)	0.40c (0.02)
HPMCF	2.53b (0.61)	6.64b (1.08)	6.25b (1.07)	5.87a (1.58)
HPMCK	1.93b (0.50)	5.84b (0.13)	6.09b (0.12)	0.88bc (0.03)
MCA	3.04b (0.28)	6.98b (1.03)	7.13b (0.07)	0.78bc (0.20)

In the same column, values with the same letter are not statistically different according to the Tukey test ($p< 0.05$).

Oscillatory test

The mechanical spectra of the different dough formulations are shown in Fig. 2. All formulations presented a typically behaviour of weak gels with G' values higher than G'' and a slight dependence with frequency (Fig. 2a and 2b). Similarly to the results found in the creep tests, the viscoelastic behaviour was different between the control and the cellulose emulsion doughs. The control sample showed the significant highest values of G' and G''. On the other hand the MC dough showed the lower values of both G' and G''. Finally all the HPMC samples (E, F and K) presented similar values, which were slightly higher than the values of the MC dough. The lower values of both G' and G'' in all the cellulose doughs are in concordance with the lower resistance to deformation found in the creep test in comparison to the control and reveal the behaviour of weaker gels with a less structured network.

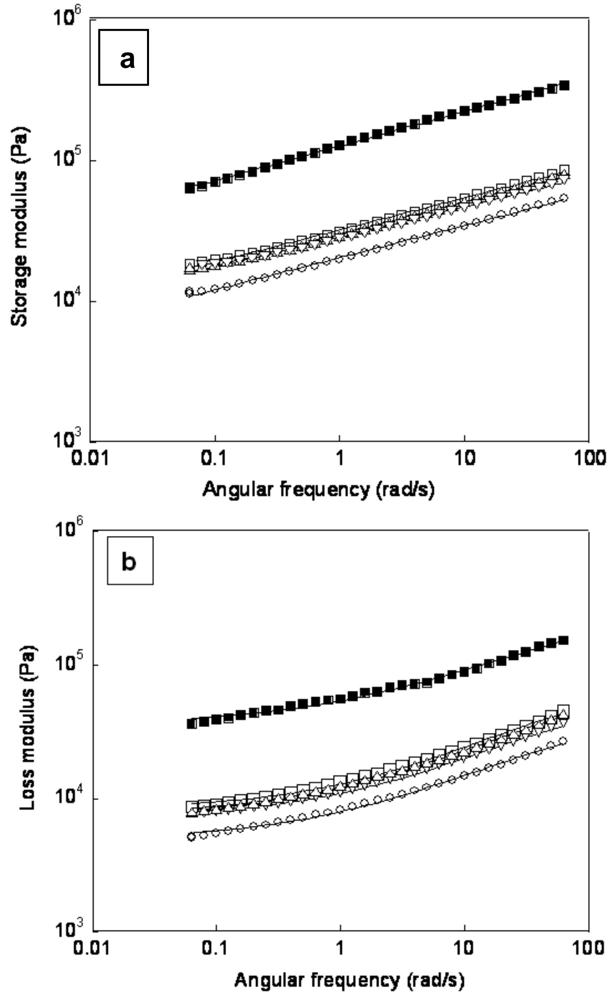

Figure 2. Mechanical spectra of the different dough formulations. Storage modulus (a) and loss modulus (b) as a function of frequency ■ Control, □ HPMC E, △ HPMC F, ▽HPMC K, ○ MC A.

To better understanding the behaviour of the samples the dependence of the viscoelastic modulus with frequency was analysed. The dependence of G' with frequency corresponds to straight lines in the log-log plot for all the samples. This dependence can be fitted to a power law equation (Eq. 2):

$$G' = K' \omega^{n'} \qquad (2)$$

where, n' is the power law index related to the slope of the straight lines in the log-log scale and K' corresponds to the values of the moduli for ω=1 rad/s.

On the other hand, the dependence of G'' with frequency can be fitted satisfactorily to the empirical equation described by Dolz et al. (2006) (Eq. 3):

$$G'' = K'' - Ze^{(10-0.08\varpi^{0.6})} \qquad (3)$$

where, K'' corresponds to the G'' values for very low frequencies and Z reflects the dependence of G'' with frequency. Values of these parameters are shown in Table 3. Considering the correlation coefficient values (r), G' and G'' values fitted well to the model for the five systems studied (r>0.999 for G' and r>0 .996 for G''). No differences in n' were found among the cellulose doughs, indicating that the frequency dependence of G' was the same in all the samples on the frequency window studied. The control sample showed a slightly, although significant, higher value (closer to 1) of n', which indicates a slightly higher frequency dependence. The evolution of the parameter K' was the one already commented for G', characterized for significantly higher values in the control and significantly lower values for the MC emulsion. The parameter K'' followed the same trend than K' with significantly higher values in the control dough.

Finally the parameter Z was significantly lower for the cellulose emulsion doughs than for the control.

Table 3. Values of the parameters obtained from equations 2, 3 and 4.

Samples	$G'=K'\omega^{n'}$		$G''=K''-Ze^{(10-0.08\varpi^{0}}$		$\log(\tan\delta)=A(\log\varpi)^2 + B(\log\varpi)-0.377$		
	K' (Pa)	n'	K'' (Pa)	Z	A	B	ω_{min} (rad/s)
Control	121540a (7213)	0.247a (0.001)	225815a (177)	8.59a (0.14)	0.051a (0.003)	-0.064a (0.006)	4.38a (0.92)
HPMCE	32276b (102)	0.226b (0.001)	65623b (344)	2.60b (0.01)	0.032b (0.001)	-0.005b (0.002)	1.20b (0.07)
HPMCF	30662b (983)	0.229b (0.001)	63605b (1317)	2.53b (0.05)	0.023c (0.003)	-0.007b (0.002)	1.40b (0.11)
HPMCK	29917b (1798)	0.218b (0.004)	56270c (3698)	2.20b (0.14)	0.030b (0.003)	-0.005b (0.003)	1.19b (0.11)
MCA	19106c (1880)	0.222b (0.009)	36252d (4617)	1.42c (0.20)	0.032b (0.001)	-0.005b (0.002)	1.20b (0.07)

In the same column, values with the same letter are not statistically different according to the Tukey test ($p < 0.05$).

The evolution of tanδ with the frequency can be seen in Figure 3. Again, the behaviour of the cellulose emulsion doughs was different than the control dough. In the latest it can be observed a more solid behaviour at higher frequencies and a more liquid behaviour at lower frequencies whereas tanδ in cellulose emulsion dough's practically did not vary in the frequency range studied. Therefore, it could be said that the replacement of shortening by the cellulose emulsion induces a change in the network structure of the dough

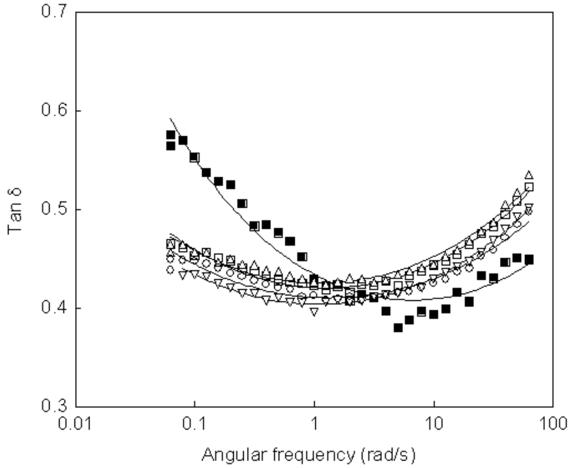

Figure 3. tan δ as a function of frequency for the different formulations ■ Control, □ HPMCE, △ HPMCF, ▽HPMCK, ○ MCA

The dependence of tanδ with frequency can be adjusted to the following equation (Eq. 4):

$$\log(\tan\delta) = A(\log\varpi)^2 + B(\log\varpi) - 0.377 \qquad (4)$$

Values of the parameters A and B are shown in Table 2 and the value of the frequency at which δ reaches a minimum (ω_{min}) was also calculated for each sample (Sopade, Halley, D'Arcy, Bhandari, & Caffin, 2004). Significant differences in these parameters between control sample and cellulose emulsion samples were found. This reveals the significant structural changes that occurred due to conventional fat replacement by the cellulose emulsion. No differences with the type of cellulose were found.

Correlations between creep and oscillatory results, dough texture, biscuit texture and spread properties.

To better understanding the relationship among the creep and oscillatory results and the values of the dough texture, the biscuit texture and the biscuit dimensions measurements obtained in a previous work (Tarancón et al., in press), a principal component analysis (PCA) was carried out (Figure 4).

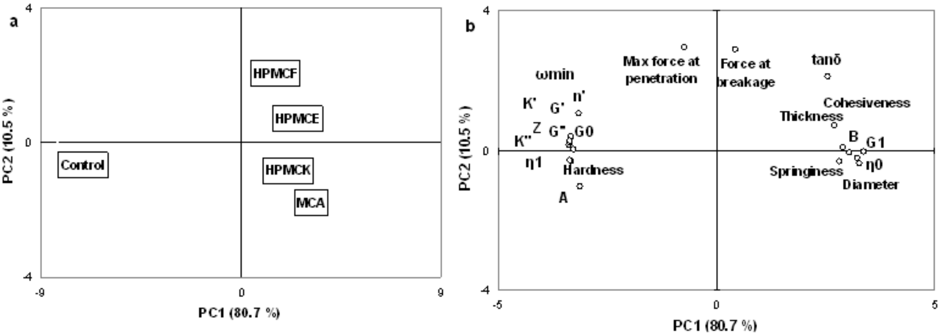

Figure 4. Two-dimension PCA plot of the variations in rheological parameters, textural parameters and dimensions among control dough and cellulose ethers dough.

The first two components explain 91.2% of the differences among samples. The first component that explains 80.7% of the variance clearly separates the cellulose doughs from the control. All the cellulose doughs appear in the positive part of PC1, while the control dough appears separated in the negative part. The cellulose doughs are related to the creep parameters G_1 and η_0 and with the biscuit diameter and thickness. The texture dough parameters cohesiveness and springiness also appear separated in the positive part of PC1. In the negative part of PC1, associated to control sample, appear the creep parameters G_0 y η_1, the oscillatory parameters (G' and G'') and the dough texture parameter hardness.

As explained before the highest values of G' and G'', together with the highest values of the creep parameter G_0 and the highest texture parameter hardness reflect the higher resistant to deformation and the highest elasticity of the control dough in comparison to the cellulose emulsion dough. The lower values of G', G'', G_0 and hardness in the cellulose emulsion doughs explained the higher spread (higher diameter) of the biscuits during baking due to their lower resistance to deformation and lower elasticity. In this regard, it is important to emphasize the peculiar properties of the cellulose emulsion biscuits: they have higher diameter but also higher thickness. This combination is not usual as higher diameter is commonly associated to lower thickness: biscuit increase in one dimension and decrease in another. The higher diameter in the cellulose biscuits can be explained due to the lower resistant to deformation and the lower elasticity. On the hand the higher thickness should be associated to other specific properties of the cellulose doughs, such as for example the thermogeling ability, which occurs during heating in the oven.

The second component explains 10.5% of the differences and separates in the positive part the biscuit texture parameters: maximum force of penetration and three point bending breaking force. These two texture parameters are not related to any other parameters or sample. This result is related to the fact that all the types of biscuits showed similar texture properties, despite their differences in dough rheological and dough texture properties. The similarity in the biscuit texture properties among the control and the cellulose doughs is one of the positive aspects of the employ of the cellulose emulsion as fat substitute, as reduction of fat content has always been associated with a negative increase in biscuit hardness. Therefore the differences in dough rheology and texture can only explained the biscuit dimension parameters.

CONCLUSIONS

The study of the viscoelastic properties by creep and oscillatory tests allows to better understand the inner structure of the doughs and provides an explanation for the obtained differences in biscuit diameter. Clear differences in the viscoelastic properties among the control dough and the dough formulated with the cellulose emulsion were found. The type of cellulose did not exert a significant influence in the viscoelastic properties.

In the creep tests, the cellulose emulsion doughs showed significantly lower resistance to deformation and lower instantaneous deformation, which reflect a lower elastic nature and lower recover ability. The oscillatory tests also reveal the existence of a more liquid like structure, with lower values of the elastic and loss modulus in the cellulose emulsion doughs. The obtained viscoelastic results (lower dough consistency and lower elasticity) explained the higher spreadness of the cellulose biscuits, which confers higher diameter to the final biscuit. The observed similarity in biscuit texture properties among the control biscuit and the cellulose emulsion biscuits can not be explained on the basics of dough viscoelastic properties at ambient temperature. Very probably the thermal gelation associated to the cellulose ether could be the reason to explain the similarity in the biscuit final texture despite such a big difference in the initial dough structure.

ACKNOWLEDGMENTS

The authors wish to thank the Spanish Ministry of Science and Innovation (AGL 2009-12785- C02-019 for the financial support and The Dow Chemical Co. (Michigan, USA) for providing free samples of the ingredients.

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CAPÍTULO 3

Formulating biscuits with healthier fats. Consumer profiling of textural and flavour sensations during consumption

Food Research International, 53 (2013), 134-140

FORMULATING BISCUITS WITH HEALTHIER FATS. CONSUMER PROFILING OF TEXTURAL AND FLAVOUR SENSATIONS DURING CONSUMPTION

P. Tarancón, S.M. Fiszman, A. Salvador, and A. Tárrega

ABSTRACT

The objective of this work was to study the changes in sensory properties of biscuits when using new oil/hydrocolloid systems and/or when reducing fat to diminish saturated fatty acids content. Free Choice Profile (FCP) combined with the Repertory Grid (RG) method was used to determine the differences perceived by naive consumers at different stages of the eating process. Fourteen biscuits containing different types of fat (five oil/hydrocolloid systems and two conventional shortenings) were prepared at two fat levels (15.6% and 10.6%) and compared with two control biscuits prepared with the two conventional shortenings at 18% fat level. Sensory characteristics of biscuits were evaluated by consumers (n=28) using their own set of descriptors. Generalized Procrustes Analysis (GPA) was applied to data to determine differences perceived during each stage (first bite, during chewing, and during bolus aggregation/ swallowing). Consumers agreed in using hardness to describe the differences among biscuits perceived at first bite. During chewing differences in other texture attributes and the main flavours in biscuits were found by some consumers. During the last eating period, consumers perceived clear differences in these main flavours but also in some other flavour notes.

A substantial reduction in the fat content (10.6% fat) resulted in biscuits that were considerably harder and drier and had less flavour than the control ones (18% fat). A less drastic fat reduction (15.6% fat) made it possible to prepare biscuits which retained similar sensory properties to those of the controls. The biscuits prepared with either olive oil or sunflower oil and xanthan gum differed the most from the biscuits made with shortenings. The biscuits formulated with either olive oil or sunflower oil and HPMC had the closest sensory properties to the shortening biscuits. The sunflower oil/HPMC systems seemed to be the most suitable system for obtaining biscuits with a healthier fatty acid profile.

Key words: Biscuits, healthier fatty acid profile, texture, flavour, Free Choice Profile.

INTRODUCTION

Biscuits are the most popular bakery items consumed by nearly all levels of society. Fat plays a decisive role in this baked product and some important sensory characteristics are strongly dependent on the fat type and content, as fat imparts shortening, richness and tenderness, and also improves mouthfeel and flavour delivery (Pareyt & Delcour, 2008; Hadnadev, Dokić, Hadnadev, Pajin, & Krstonošić, 2011). Shortenings or solid fat products are needed in biscuit manufacturing because they have suitable plasticity properties (consistency, high melting temperature), allowing the air to be incorporated during dough formation and enabling the dough to withstand the high temperatures reached during baking and hold its shape for longer (Litwinenko, Rojas, Gerschenson, & Marangoni, 2002; Lee, Akoh, & Lee, 2008). The most frequently used plastic fats are margarine, manufactured shortenings and butter, all of which contain high levels of saturated fatty acids and in some cases trans-fatty acids (Ghotra, Dyal, & Narine, 2002). The negative cardiovascular and metabolic health effects associated with trans and saturated fats are leading to an increased interest in developing novel semi-plastic shortening structures, without undesirable hydrogenated or saturated fats, for use in food applications (Goldstein & Seetharaman 2011). Hence, fat content reduction and the use of fats with a healthier fatty acid profile are alternatives for developing new formulations that respond to the consumer demand for products that are “good for you”.

Several authors have studied the effect of partial fat replacement in biscuits, mainly with different carbohydrate-based fat replacers like polydextrose, maltodextrin, guar gum or inulin (Kaur, Singh, & Kaur, 2000; Sudha, Srivastava, Vetrimani, & Leelavathi, 2007) but also with protein based fat replacers like a microparticulate whey protein blend (Zoulias, Oreopoulou, & Kounalaki, 2002) or lupine extract (Forker, Zahn, & Rohm , 2012). In general, the physical and sensory properties of biscuits prepared with fat replacers differ from those of conventional biscuits: they are harder and more brittle and have a higher moisture content and water activity (Zoulias et al., 2002; Seker, Ozboy-Ozbas, Gokbulut, Ozturk, & Koksel, 2010).

Avoiding the presence of trans fatty acids and avoiding the use of saturated fats are two strategies for using healthier fats. A solid fat obtained by transesterification of vegetable edible oils is free of trans fatty acids but still has a high percentage of saturated fatty acids. An interesting alternative is to use a liquid vegetable oil entrapped within a gel network. By giving the oil solid-like properties, these gels may potentially be used as fat mimetics, improving the fatty acid profile of the food product while maintaining its positive sensory properties (Gravelle, Barbut, & Marangoni, 2012; Stortz, Zetzl, Barbut, Cattaruzza, & Marangoni, 2012).

Most of the studies in the literature use conventional descriptive analysis (QDA) to describe differences in the sensory properties of biscuits. Descriptive analysis involves selecting and developing a consensus list of descriptors, so experienced assessors are trained in the use of oriented terms that sometimes tend to be quite complex. For this reason, information on the spontaneous sensations that actually occur when a product is eaten is lost (Varela & Ares, 2012). To avoid these disadvantages and obtain more direct information about the sensations that consumers perceive while eating, Free Choice Profile (FCP) can be used with the Repertory Grid (RG) method as a previous step. FCP differs from conventional profiling in that each consumer develops an individual list of terms to describe the samples rather than having a common scorecard. It remains similar in that the consumers must be able to detect differences between samples and verbally describe and quantify the perceived attributes (Oreskovich, Klein, & Sutherland, 1991). RG involves triadic or dyadic comparisons of products in one-on-one interviews in which consumers elicit their own set of “constructs” to describe similarities and differences between particular products (Russell & Cox, 2003).

Owing to the fact that sensory perception occurs throughout the eating process, the consumers’ perceptions must be understood in relation to time-dependent processes during the act of eating. There is an increasing amount of information about the dynamics of texture perception during mastication (where the physical properties of the food bolus are constantly changing over time) and how this relates to overall texture perceptions of a food product (Chen, 2009; Foster et al., 2011).

During eating, solid foods are subjected to a three-stage process. First the food is transported from the front of the mouth to the post-canine teeth, then in the second stage the food is fragmented by the teeth and its progressive impregnation by saliva begins to result in the formation of a cohesive bolus, and finally the food is passed backwards to the oropharynx where the bolus is swallowed (Hiiemae & Palmer, 1999).

The dynamics of sensory perception has mainly been studied with trained panellists using time intensity and temporal dominance sensation (TDS) techniques (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009; Laguna,Varela, Salvador, & Fiszman, 2013; Pineau et al., 2009).

Time intensity techniques give information about the evolution of the intensity of given attributes but only one attribute can be evaluated at a time (Dijksterhuis & Piggot, 2001). TDS techniques consist in identifying and rating both the sensations perceived as dominant at each instant of eating, until the perception ends, and the intensity of these sensations over the eating period (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009). However, there are fewer studies evaluating differences among products perceived by naïve consumers during consumption (Albert, Salvador, Schlich, & Fiszman, 2012).

The objectives of this work were a) to evaluate the using of Free Choice Profile method to know how consumers perceived the sensory properties of biscuits with different fat types and levels using oil/gel systems to replace saturated fat; and b) to describe differences perceived at the different stages of the eating process.

MATERIAL AND METHODS

Ingredients and Biscuit Preparation

Ingredients. Soft wheat flour (Belenguer, S.A., Valencia; composition data provided by the supplier: 11% protein, 0.6% ash; alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), sugar (Azucarera Ebro, Madrid, Spain), skimmed milk powder (Central Lechera Asturiana, Spain), salt, sodium bicarbonate (A. Martínez, Cheste, Spain) ammonium hydrogen carbonate (Panreac Quimica, Barcelona, Spain) and mineral water (Fontvella, Urgell, Spain). Two solid fats were used: a dairy-based shortening (Vandemoortele, Diexpa ref. 402684) and a vegetable-based shortening (Vandemoortele, Diexpa ref 406965). In the preparation of oil/gel systems sunflower oil (Coosol, Jaén, Spain), olive oil (Fontoliva, Jaén, Spain), hydroxypropyl methylcellulose (HPMC, Methocel Food Grade K4M FG, The Dow Chemical Co., Midland, MI, USA) and xanthan gum (Santiaxane CX-91, Cargill, Martorell, Spain), glycerol (Panreac Quimica, Barcelona, Spain) and butter aroma (Lucta, Barcelona, Spain, ref. 49994A).

Experimental design. Two control biscuit samples were prepared with the two shortenings at 18% fat (fat content commonly found in commercial biscuits in the market). Fourteen other biscuits with reduced fat contents (15.6% and 10.6%) and seven types of fat (the two shortenings and five oil/gel systems) were also prepared. The oil/ gel systems varied by type of oil (sunflower or olive) and type of thickener (HPMC or xanthan gum). A fifth system was prepared with sunflower oil and HPMC and flavoured with butter aroma. The types of fat and identification codes are given in Table 1.

Table 1. Identification of the fat source of the biscuits

Type of fat	Code
Dairy shortening	DAI
Vegetable shortening	VEG
Sunflower oil/ HPMC system	SUN HPMC
Sunflower oil/ xanthan gum system	SUN XAN
Olive oil/ HPMC system	OLI HPMC
Olive oil/ xanthan gum system	OLI XAN
Sunflower oil/ HPMC plus butter aroma system	SUN HPMC AROMA

Oil/gel systems. To prepare the oil/HPMC system, the proportions of oil, water and thickener employed were 47%, 51% and 2%, respectively. The HPMC was firstly dispersed in oil using a Heidolph stirrer and the mixture was then hydrated by gradually adding the water while continuing to stir. In the xanthan gum system the proportion of oil, water and thickener employed were 47%, 52% and 1%, respectively. This mixture was made by first hydrating the gum and then adding oil while continuing to stir.

Biscuit preparation. The shortening or oil/gel system, sugar (17%), skimmed milk powder (1%), salt (0.6%), sodium bicarbonate 0.2%, ammonium hydrogen carbonate 0.11% and water were mixed in a mixer (Kenwood Ltd., UK) for 1 min at low speed (60 rpm). In flavoured formulations, butter aroma (0.09%) was added in this step and in all formulations with oil/gel systems, glycerol (1.8%) was added to control the a_w. The bowl was scraped down and the mixture was mixed again for 3 min at higher speed (255 rpm). Then, the flour was added (57.5%) and mixed in for 20 s at 60 rpm then for a further 40 s at 60 rpm after scraping down the bowl once more. Fat shortening or oil/gel systems were added to achieve 14%, 12.5% and 8.5% fat content in the dough (final fat contents of 18%, 15.6% and 10.6%, respectively in the biscuits). The dough was sheeted (3.4 mm in thickness) with a sheeting machine (Parber, Bilbao, Spain) and moulded into discs of 64 mm in diameter. Twenty biscuits were placed on a perforated tray and baked in a conventional oven (De Dietrich, Basingstoke, UK) for 20 min at 170ºC (turning the tray 180° after 10 min to ensure homogenous baking). The oven and the oven trays were always the same, the trays were placed at the same level in the oven and the number of biscuits baked was always the same.

After cooling, the biscuits were packed in heat-sealed metalized polypropylene bags, stored and evaluated after 24 h.

Sensory Evaluation

A group of 28 consumers (16 women and 12 men) from 23 to 65 years old participated in the sensory evaluation.

In the first session the vocabulary used by each consumer to describe the differences among biscuits was generated by the Repertory Grid Method. In individual interviews, samples were presented in triads to each participant and he/she was asked to describe the similarities and differences of texture and flavour within each triad in his/her own terms. The order of triad presentation was balanced among the consumers (Gains, 1994) and each consumer assessed four triads.

In the second session each consumer was provided with a table with his/her own list of terms and was asked to try some different samples and indicate at which stage or stages of the eating period he/she perceived the sensation corresponding to each term: (1) at the first bite, (2) during chewing or (3) during bolus aggregation and swallowing.

Finally, a set of four sessions were performed where the sensory characteristics of the sixteen biscuit formulations were evaluated by Free Choice Profile (FCP). Individual score sheets were prepared with each consumer's descriptors. The consumers rated the intensity of each term for each sample using a 10-cm unstructured line-scale. The sixteen biscuits were evaluated by all consumers over four sessions. Each consumer evaluated four samples per session in a standardised test room with separate booths. In each session, the samples were presented following a balanced design to avoid a serving order effect.

Data Analysis

Generalized Procrustes Analysis (GPA) was applied to the FCP data using Senstools Version 3.3. Procrustes analysis of variance (PANOVA) was used to assess the differences between samples and between subjects. The total data set and the data for each biscuit consumption period were analysed separately.

RESULTS AND DISCUSSION

Terms used by consumers to describe the sensations perceived during biscuit consumption

To describe the sensory differences among biscuits, the consumers generated a total of 254 descriptors. Of these, 119 were related to flavour and 135 to texture, with individual sets ranging from 5 to 14 descriptors. Table 2 shows the terms mentioned by consumers to describe differences among biscuits during the different stages of consumption. The consumers described the sensations perceived during the first bite with texture-related terms. Hardness was the term used by all the consumers and some also used other descriptors like crunchy, mealy and brittle. The consumers therefore agreed in using hardness to describe the sensation perceived when biting a biscuit. According to Booth, Earl and Mobini (2003), this arises from the force required for initial compression of the unbroken surface by the incisor while the surface is still dry.

Table 2. Instrumental parameters obtained from the force-distance and sound-distance curves. A number of sound and force peaks were obtained at different threshold levels, as indicated

First bite	Chewing	Bolus aggregation and swallowing
Hardness (n=28)	Biscuit flavour (n=14)	Biscuit flavour (n=24)
Crunchy (n=5)	Crisp (n=14)	Buttery flavour (n=24)
Mealy (n=4)	Mealy (n=13)	Sweet (n=16)
Brittle (n=3)	Buttery flavour (n=10)	Mealy (n=11)
	Dry (n=9)	Dry (n=11)
	Hard (n=7)	Roasted flavour (n=9)
	Easy to chew (n=7)	Off-flavours (n=9)
	Sweet (n=6)	Unpleasant aftertaste (n=8)
	Roasted flavour (n=5)	Flavour notes: cereal, caramel, coconut, milk (n=8)
	Crunchy (n=5)	Easy to swallow
	Fat flavour	Fat flavour
	Fat mouthfeel	Fat mouthfeel

In brackets, the number of times that the descriptor was mentioned, if more than once

A wider range of terms was generated to describe the differences perceived during chewing, and the terms differed between consumers. That could indicate not only that the number of sensations perceived was higher but also that consumers used different terms to describe the sensations they perceived. This could be attributable in part to the higher complexity of the processes involved in this stage of eating: during chewing, the biscuit pieces are coated and impregnated by saliva, sheared and progressively fragmented, and all these actions constitute a dynamic source of multiple stimuli in the mouth. The consumers used different textural descriptors related to the behaviour of a material when crushed and moistened in mouth, like mealy, crisp, crunchy, hard, easy to chew, and dry. In addition, the first flavour sensations were also noticed by consumers during this eating stage. These terms described the main flavours of a biscuit, like sweetness and biscuit, buttery and roasted flavours.

During the last part of the eating period, flavour terms predominated over textural ones. Besides the main flavours mentioned above, a wide range of different flavour notes like cereal, caramel, cinnamon, coconut and milk were elicited from the consumers, who even mentioned some unpleasant after-tastes and off-flavours. Mealy, dry and easy to swallow were the textural terms used to describe differences related to bolus formation and swallowing.

The results indicated that only some consumers noticed the main flavours of biscuits during chewing, while most consumers clearly perceived the main flavours, and also some flavour notes, during bolus aggregation and swallowing (Table 2). This confirms that the dynamics of flavour perception is influenced by the different events taking place in the mouth, since the availability of volatile compounds depends on their release from the new surfaces created by crushing and their transfer to the olfactory receptors in the nose cavity. Studies of the dynamics of aroma release have shown that there can be pulses of aroma from the mouth to the nose during mastication of solid foods, but the maximum amount of aroma concentration in the nose is reached after swallowing, due to the position of the bolus in the proximity of the retronasal air flow by which volatile compounds are transported to the nasal cavity (Hodgson Linforth, & Taylor, 2003;Tarrega, Yven, C., Sémon, E., & Salles, 2011).

Consequently, the concentration of volatile compounds in the nose was still low during biscuit chewing and the concentration of compounds responsible for basic flavours only reached the perception threshold of some consumers. Just before and after swallowing, the volatile compound concentration was high enough for most consumers to receive sensations from both the basic flavour compounds and those that gave rise to other flavour notes.

Sensory differences among biscuits with different fat types and content

The three dimensional GPA plot obtained from analysis of the consumers assessment of the biscuits is shown in Fig. 1; the individual sensory descriptors explained by each dimension are listed next to each dimension. The total amount of variance explained by the first three dimensions of the average configuration for the consensus map of the sixteen samples was 65.86%. Dimension 1 accounted for 46.03% of the variance and was mainly related to textural terms. On the right side of the plot, terms like hard, hard to chew, dry and crispy or crunchy appeared. The 10.6% fat biscuits prepared with xanthan gum (OLI XAN and SUN XAN), perceived as both the hardest and driest biscuits, appeared in the right side of dimension 1. Terms like mealy, crunchy and crispy, some flavour sensations like butteriness, biscuit aroma and sweetness appeared on the left (Fig. 1). The samples that stood apart in the left side of dimension 1 were the two control samples and the sample with a 15.6% fat content made with vegetable shortening, which were mealier and weaker and had a more intense biscuit flavour, buttery flavour and fat flavour than the rest of the samples. In general, the samples appeared distributed along dimension 1 according to their fat content and type. Regarding the type of fat, a decrease in fat content moved the samples to the right side, indicating that the biscuits had become harder and drier and had less flavour, although these effects depended on the type of fat.

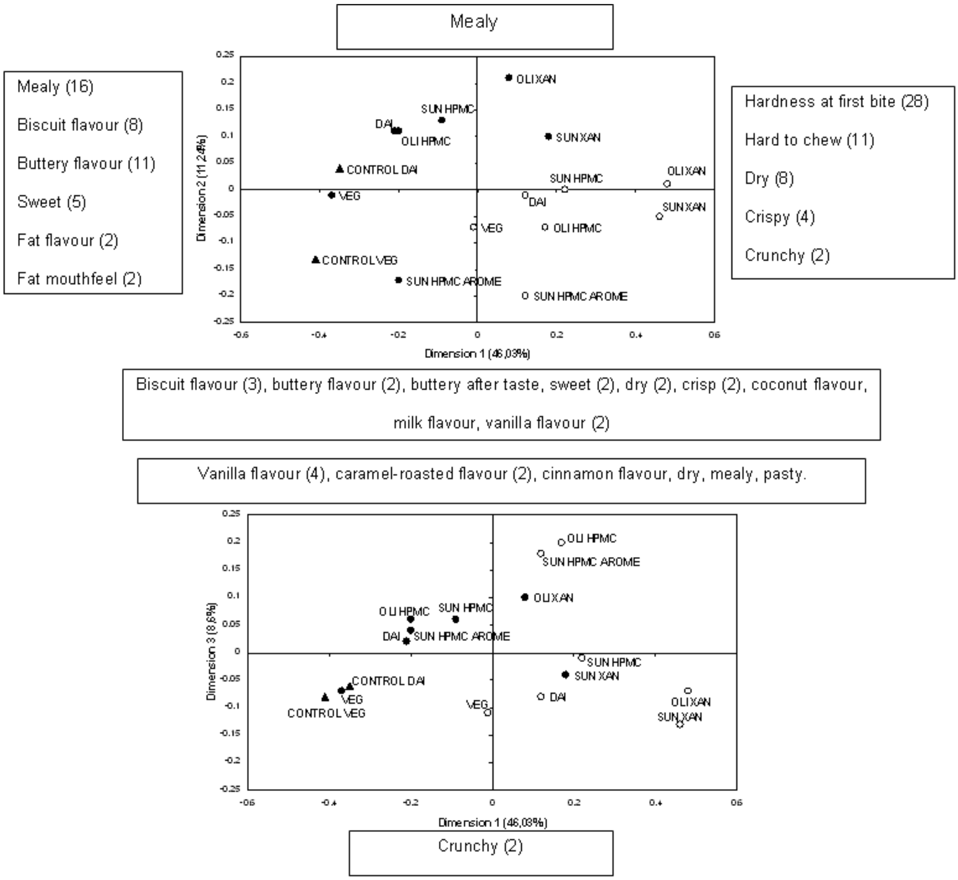

Figure 1. Three dimension GPA plot of the differences between biscuits perceived by consumers. Samples with 18% (▲), 15.6% (●) and 10.6% fat content (○). Fat type codes according to Table 1. Descriptors correlated (R>0.6) with the first three dimensions of the average space are listed on the boxes and the number of times that the descriptor was mentioned, if more than once.

Biscuits formulated with shortening at the first reduction level (15.6% fat content in the final biscuit) appeared close to both the control samples, indicating that the sensory characteristics related to dimension 1 did not change much. When oil/gel systems were used to give a 15.6% fat content, the samples moved slightly to the right in dimension 1, indicating that these samples became harder, drier and less mealy. The distance between samples depended on the type of thickener used. Biscuits containing HPMC appeared closer to those made with shortenings, being more similar to them in hardness, dryness, mealiness and flavour than the biscuits made with xanthan gum, which were found further away, implying that the changes in these attributes were considerably greater. Dimension 2, which accounted for 11.24% of the variance, was positively related to mealiness and negatively related to biscuit, buttery, vanilla, coconut and milk flavour notes. The distribution of samples along dimension 2 mainly varied according to the type of fat used to prepare the biscuits. The samples with the flavoured sunflower oil system (SUN HPMC AROME) and the control with vegetable shortening, which elicited more flavour sensations, appeared separately at the bottom of the plot. These flavour notes (described as buttery, vanilla, cinnamon and coconut) were less intense in biscuits made with dairy shortening or with the liquid oils. The third axis (8.6%) was positively related to flavour notes like caramel and cinnamon and to mealy and pasty texture and negatively related to crunchy texture. According to the sample positions, these flavour notes and pasty texture differentiated the biscuits made with liquid oil from those made with shortenings. At the lowest fat content (10.6%), the biscuits prepared with oil and HPMC presented more intense flavour notes and a pasty, less crunchy texture than those with shortening or oil/xanthan gum and dimension 3 separated them into the top and bottom half respectively.

Sensory differences among biscuits during each eating period

With the aim of gaining a better understanding of the variability in the consumers' sensory perceptions, three GPAs were performed to take the results obtained during the different eating stages into account, attempting to determine how the differences among samples were perceived during each stage (first bite, during chewing, and during bolus aggregation and swallowing).

The GPA plots are shown in Fig. 2 and attributes with correlations higher than 0.6 for each dimension are also shown in Table 3.

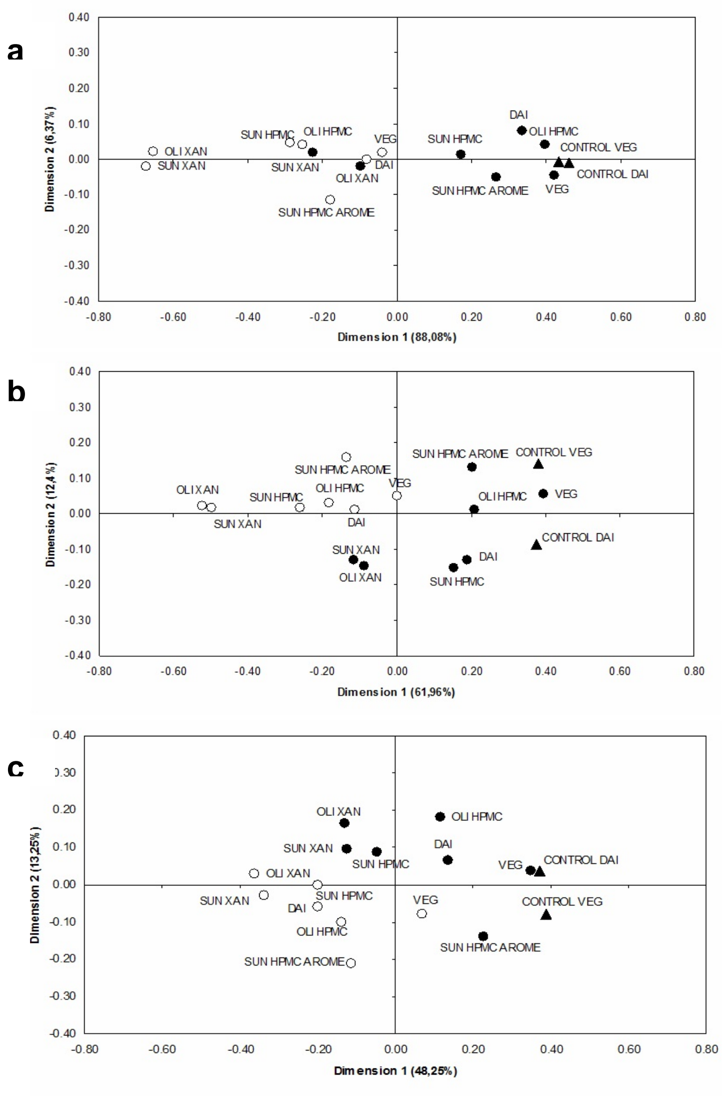

Figure 2. Two dimension GPA plot of the differences between biscuits perceived by consumers during first bite (a), chewing (b) and bolus aggregation and swallowing (c). Samples with 18% (▲), 15.6% (●) and 10.6% fat content (○). Fat type codes according to Table 1.

Table 3. Descriptors correlated (R>0.6) with the first two dimensions during each stage of biscuit consumption

Eating period	Dimension	Correlation	Descriptors
FIRST BITE	1	Positive	Mealy, brittle
		Negative	Hardness at first bite (28), dry (2), crunchy (2), noisy (2), easy to chew
	2	Positive	Easy to chew, crunchy
		Negative	Vanilla flavour
CHEWING	1	Positive	Mealy(9), crisp (3), easy to chew (2), soft texture (3), brittle (2), fat mouthfeel (2), crunchy, biscuit flavour (6), buttery flavour (3), sweet (2) fat flavour
		Negative	Hard to chew (10), dry (6), hard (5), crisp (5), crunchy (2)
	2	Positive	Crisp (2), dry, vanilla flavour (3), buttery flavour (2), sweet
		Negative	Mealy
BOLUS AGGREGATION AND SWALLOWING	1	Positive	Buttery flavour (11), sweet (4), biscuit flavour (5), fat flavour (2), buttery aftertaste, fat mouthfeel (3), soft texture (3), mealy (8), easy to chew, easy to swallow, moist
		Negative	Dry (4), hard to chew (4)
	2	Positive	Off flavour, mealy
		Negative	Buttery flavour (2), biscuit flavour (2), fat flavour, milk flavour, dry

First eating stage: First bite

The total variance explained by the first two dimensions of the average configuration was 94.45% (Fig. 2a). Dimension 1 accounted for 88.1% of the total variance, indicating that most of the differences between biscuits perceived during the first bite were explained by this dimension and it was mainly related to hardness but also to crunchiness and dryness (Table 3). The high variance explained by the first dimension indicated that consumers coincided in the differences perceived among biscuits. Consumers also agreed in using hardness for describing the differences which suggested that it is a "well understood" attribute for consumers. Three groups of samples were differentiated (Fig. 2a). In the group on the left side of the plot are the samples made with oil/xanthan gum system at the lowest fat content, which were perceived as the hardest samples. Further to the right is a group of biscuits with intermediate hardness (most with a 10.6% fat content but also oil/xanthan gum biscuits with a 15.6% fat content). Finally, the group on the far right includes the control biscuits (18% fat) and those containing 15.6% fat made with shortenings and oil/HPMC, which were all perceived as similar (not very hard).

Second eating stage: During chewing

Unlike the first bite stage, more than one GPA dimension was necessary to explain most of the variability in the chewing stage (Fig. 2b). The first dimension accounted for 61.96% of the variance. The negative side of the plot was related to hardness, crunchy or hard to chew and the positive side was mainly linked to mealy and also to a few flavour descriptors like biscuit flavour intensity, sweetness and buttery flavour (Table 3). The second axis explained 12.4 % of the total variance and was positively related to buttery and vanilla flavours.

According to the GPA plot, the consumers perceived more differences among samples during this period. When samples that were perceived as having similar hardness during the first bite were chewed, they were differentiated according to their hardness, crunchiness and flavour intensity. During this eating stage, CONTROL VEG, VEG and CONTROL DAI (15.6% fat content) were perceived as being similar in texture to each other but different in texture from SUN HPMC AROME, OLI HPMC, DAI and SUN HPMC (15.6% fat content). The first of these two groups was found to be mealier, easier to chew and sweeter and to have a more intense buttery aroma than the second group.

Taking the second dimension into account, the perception of aroma compounds during chewing also differentiated biscuits made with vegetable shortening or the flavoured oil/gel system (SUN HPMC AROMA) from those made with dairy shortening or with the other oil/gel systems, as the former had more intense buttery and vanilla flavours.

Third eating stage: Bolus aggregation and swallowing

The first two GPA dimensions of the average configuration explained 61.14% of variance when considering sensations perceived during the last stage of biscuit eating. The first dimension accounted for 48.25% of the total variance and explained differences in buttery flavour and sweetness (positive part) and dryness (negative part) between the samples. The second dimension, which explained 13.25% of the variance, was positively related to off-flavours and negatively related to milky and biscuit flavour.

As can be observed in the GPA plot (Fig. 2c), the differences in hardness observed earlier were perceived as differences in dryness and the differences in buttery flavour already observed during chewing became more evident during this last stage. In addition, the 15.6% fat biscuits made with olive oil/HPMC presented an off flavour that was only perceived during this stage. Finally, a third dimension (plot not shown) explained differences in flavour between biscuits with vegetable shortening and biscuits with flavoured oil/gel systems, as the latter presented caramel or roasted notes that were not found in the former.

The differences in both the textural and flavour characteristics of the biscuits were mainly due to different fat contents, while the type of fat had less effect. Regarding fat content reduction, the results showed that for conventional shortenings, a substantial (41%) reduction in the fat content resulted in biscuits (10.6% fat) that were considerably harder and drier and had less flavour than the controls (18%). However, a less drastic fat reduction (13.8%) made it possible to prepare biscuits (15.6% fat) which retained similar sensory properties to those of the controls. From a sensory point of view, vegetable shortening proved more suitable than dairy shortening for fat reduction (to a 15.6% fat content) because the sensory characteristics of the vegetable shortening biscuits remained closer to those of the control samples.

Regarding replacement of shortenings with oil/gel systems, the changes in the sensory properties of the biscuits varied depending on the system used. Those prepared with xanthan gum differed the most from the shortening biscuits and were generally hard and dry and with less flavour. The biscuits formulated with either olive oil or sunflower oil and HPMC had the closest sensory properties to those of the biscuits made with shortenings. Some consumers perceived an off–flavour in the biscuits containing olive oil. Sunflower oil/HPMC therefore seems to be more suitable for achieving biscuits with a healthy fatty acid profile. In this case, butter aroma can be added to obtain a product with more intense buttery and vanilla notes.

CONCLUSIONS

RG combined with FCP was a useful tool for obtaining interesting information about the sensations that consumers perceived while consuming biscuits. In general, consumers used a wide range of individual terms for describing differences among biscuits and sometimes the same term was applied to describe different perceptions. This accounted for the difficulties of consumers in the assessment of “pre-established” attributes, and would confirm the needs of using suitable sensory techniques for evaluating consumers’ perception. However, in the case of the textural term hardness, consumers agreed using this term for describing the same sensation and the same differences among samples during the first bite. According to that, one can suppose that consumers have a similar internal scale for evaluating hardness of biscuits which validate the use of this term as a general and well understood attribute.

When removing an important part of fat in biscuits, consumers perceived important differences in both texture and flavour. However, with a moderate fat reduction biscuits with similar sensory properties to full-fat ones could be obtained. In addition, the effects of saturated fat replacement by oil/gel systems depended on fat level as changes in sensory properties of biscuits were more evident at low fat content. The use of systems with HMPC and either sunflower or olive oil resulted suitable for formulating biscuits with healthier fat profiles (free of trans and low-saturated fats) while keeping the sensory characteristics close to those of biscuits prepared with shortenings.

ACKNOWLEDGEMENTS

The authors have received financial support from the Spanish Ministry of Science and Innovation (AGL 2009-12785- C02-01 and Tarrega's contract within the Juan de la Cierva Programme). The authors also wish to thank The Dow Chemical Co. (Michigan, USA); Cargill, (Martorell, Spain) and Lucta S.A. (Barcelona, Spain) for providing free samples of the ingredients and to Gabriela van Beest for her collaboration in the experimental work.

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CAPÍTULO 4

Effect of fat on mechanical and acoustical properties of biscuits related to texture properties perceived by consumers

Aceptado para publicación en la revista *Food and Bioprocess Technolog*y

EFFECT OF FAT ON MECHANICAL AND ACOUSTICAL PROPERTIES OF BISCUITS RELATED TO TEXTURE PROPERTIES PERCEIVED BY CONSUMERS

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ABSTRACT

The objective of this study was to measure the changes in the mechanical and acoustic properties of biscuits when solid fat was replaced by vegetable oils and to relate these properties to the texture sensations perceived by consumers.

Twelve biscuit formulations containing different types of fat (two shortenings and four oil/hydrocolloid systems) and different fat contents (10.6% and 15.6%) were studied. The mechanical and acoustic properties of the biscuits were measured instrumentally by a three point bending test and two penetration tests using cylindrical and spherical probes. The values of parameters such as the maximum peak, distances, slopes, and number of events were obtained from the force-distance and sound-distance curves. . Results showed that both fat type and content affected instrumental texture of biscuits. When reducing fat content, biscuits presented high force at breaking and at penetration and more fractures during cylinder penetration. When the saturated fat was replaced by the oil/xanthan gum system, the biscuit proved more elastic, resistant to breaking and noisy during penetration. Moreover, when the fat content was decreased or the shortening was replaced with the oil/gel systems, the number of force events (>0.1 N) during sphere penetration was lower. Free Choice Profiling (FCP) was used to determine the differences in texture characteristics perceived by consumers (n=28) and relationships between the consumers' perception and instrumental parameters, was performed by partial least squares regression analysis (PLS). Results showed that higher force at breaking values and at penetration and a large amount of fractures during the cylinder penetration were related with hard and crunchy perception in biscuits. Besides, high values of the resistance to breaking parameter, and large amount of sound events were also related with an increased sensation of the hardness. Finally, a high number of microfractures (0.1 N) during the penetration with sphere was found to be related with the perception of mealy, crumbly and brittle sensations.The olive oil/HPMC system at the high fat content conferred similar mechanical and acoustical properties to those provided by the shortening fats, leading to biscuits with similar texture properties in the mouth.

Keywords: biscuit, fat, vegetable oils, texture, acoustical properties, consumers

INTRODUCTION

Biscuits are widely consumed because of their sensory characteristics, in particular their texture and taste. Margarine, manufactured shortenings and butter are fats which are frequently used in biscuit formulation because they have suitable plasticity properties (consistency and a high melting temperature), allowing the air to be incorporated during dough formation and enabling the dough to withstand the high temperatures reached during baking and to hold its shape for longer (Litwinenko et al., 2002; Lee et al., 2008). However, all these types of fat contain high levels of saturated fatty acids. A vegetable oil with a healthier fatty acid profile is proposed as an alternative for formulating biscuits with improved nutritional characteristics. Sunflower and olive oil are two interesting alternatives owing to their high unsaturated fatty acid content. Additionally, olive oil is appreciated by consumers in Mediterranean countries, though it is not commonly used as a biscuit ingredient. The use of these more unsaturated – and therefore softer – dough fats requires some investigation, particularly in terms of fat dose and dough handling. An interesting approach to giving the oil solid-like properties is to use the liquid vegetable oil entrapped within a gel network (Gravelle, et al., 2012; Stortz, et al., 2012, Tarancón et al., *in press*).

From a sensory quality viewpoint, fat is one of the principal ingredients that affect biscuit texture. As observed in many previous studies, reducing the fat content or replacing fat with other ingredients have a considerable impact on the texture attributes of biscuits (Campbell et al., 1994; Zoulias et al., 2002; Rodríguez-García et al., 2012). Like other cereal products, biscuits have a complex cellular structure whose breakdown mechanics primarily depend on its heterogeneity, the presence of voids and the multiplicity of defects from which cracking can develop (Hedjazi et al., 2011). During eating, a solid food such as a biscuit is compressed until its heterogeneous structure begins to develop cracks and eventually breaks (Booth et al., 2003a). Fat plays an important role in the mechanical properties and fracturing behaviour of biscuits, since it is responsible for the reduction of the air cell size which leads to a severe decrease in the fracture stress of the initial products (Baltavias et al., 1999).

Mechanical and acoustic instrumental tests can be used to understand and evaluate the perceived differences in texture of solid foods (Vickers, 1988; Duizer, 2001). Despite differences in how sensory and instrumental terms are evaluated, several studies have shown that instrumental parameters correlate to one or more specific texture properties. These correlations have generally been better when instrumental tests more closely mimic the intraoral processes (Duizer and Winger, 2006; Kim et al., 2009; Foster et al., 2011. Different types of measurement, such as puncture, compression or bending tests, should be used to describe the nature of the mechanical and acoustical responses of the biscuit structure in the mouth (Gaines, 1991). The force required to fracture a biscuit completely can be measured in a 3-point bending rig while the patterns of force generated by teeth pressing into the surface of the biscuits and then crushing a piece between the molars may be estimated from the force/distance profile of the cracks produced as a probe is pressed through the food material without creating a complete, fracture, as in puncture or compression tests. Therefore, the fracture profiles of a penetration test can be used as sources of adequate stimuli and can also be correlated to sensory analysis data (Gaines et al., 1992; Booth et al., 2003b).

Biscuit texture perception is a multisensory experience resulting from the biscuit's fracturing patterns during eating. As demonstrated by Mobini et al. (2010), in such complex situations subjects differ greatly from each other in their attention to the different features they sense and how they verbalise them. However, most previous studies of texture perception in biscuits have ignored individual differences in perception. Most have used quantitative descriptive analysis methods in which all the subjects used the same terminology and each of the terms were defined in the same way (Kim et al., 2011), while other studies have used one or more specific texture properties of biscuits like hardness, crunchiness or crispiness as "well-defined" terms (Lenfant et al., 2009; Booth et al., 2003). Free-Choice Profiling (FCP) is a sensory technique where each subject quantifies the perceived qualities of products using his or her own individual list of terms (Oreskovich et al., 1991; Heymann, 1994). If individuals use different criteria to define and assess the texture properties of biscuits, using FCP might help to expose these differences.

With the aim of formulating healthier biscuits, the objective of this work was firstly to determine the changes in mechanical and acoustical properties of biscuits when solid fat was replaced by vegetable oils and secondly to relate these properties with the texture sensations assessed by consumers using Free Choice Profiling.

MATERIALS AND METHODS

Samples

Twelve different biscuit formulations were studied. The biscuit samples varied in the type of fat (six types of fats: two shortenings and four oil/gel systems) and fat content (10.6% and 15.6%). The two shortenings, both commonly used in biscuit manufacture, were a shortening containing dairy fat (Vandemoortele ref. 402684 Diexpa, Valencia, Spain) and a shortening containing vegetable fat exclusively (Vandemoortele, ref 406965 Diexpa, Valencia, Spain). The oil/gel systems were prepared with sunflower oil (Coosol, Jaén, Spain) or olive oil (Fontoliva, Jaén, Spain) and a thickener (hydroxypropyl methylcellulose (HPMC, Methocel Food Grade K4M FG, The Dow Chemical Co., Midland, Michigan, USA) or xanthan gum (Santiaxane CX-91, Cargill, Martorell, Spain)). The type of fat used in each formulation and the identification codes are shown in Table 1

Table 1. Identification of the different fat sources employed

Type of fat	Identification
Dairy Shortening	DAI
Vegetable shortening	VEG
Sunflower oil/xanthan gum system	SUN XAN
Sunflower oil /HPMC system	SUN HPMC
Olive oil/ xanthan gum system	OLI XAN
Olive oil/ HPMC system	OLI HPMC

To prepare the oil/HPMC systems, the proportions of oil, water and thickener employed were 47%, 51% and 2%, respectively. The HPMC was first dispersed in oil using a Heidolph stirrer and the mixture was then hydrated by gradually adding the water while continuing to stir (Tarancón et al., 2013a). In the systems prepared with xanthan gum, the oil content was the same as in the

HPMC preparations but the thickener concentration was 1% and the water concentration 52%. This mixture was made by first hydrating the gum and then adding oil while continuing to stir.

The amounts of the other ingredients in the formulation were kept constant (dough weight basis): soft wheat flour 57.5% (Belenguer, S.A., Valencia; composition data provided by the supplier: 11% protein, 0.6% ash; alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), fat shortening or vegetable oil systems 12.5% or 8.5%, sugar 17% (Azucarera Ebro, Madrid, Spain), skimmed milk powder 1% (Central Lechera Asturiana, Spain), salt 0.6%, sodium bicarbonate 0.2% (A. Martínez, Cheste, Spain), and ammonium hydrogen carbonate 0.11% (Panreac Quimica, Barcelona, Spain). The water added in each formulation ranged from 111 g for the low fat biscuits to 45 g for the high fat biscuits. In the formulations with the oil/gel systems, glycerol (1.8%) (Panreac Quimica, Barcelona, Spain) was also added to control the a_w.

Biscuit preparation

The shortening or oil/gel system, sugar, milk powder, leaving agents, salt, water and glycerol (only in the oil/gel system formulations) were mixed in a mixer (Kenwood Ltd., UK) for 1 min at low speed (60 rpm), the bowl was scraped down and the mixture was mixed again for 3 min at a higher speed (255 rpm). The flour was added and mixed in for 20 s at low speed (60 rpm), then mixed for a further 40 s at the same speed after scraping down the bowl once more. The mixing procedure was carried out following the creaming method according to Pareyt and Delcour (2008).The dough was sheeted with a sheeting machine (Parber, Vizcaya, España) and moulded into pieces measuring 64 mm in diameter×3.4 mm thick. Twenty biscuits were placed on a perforated tray and baked in a conventional oven (De Dietrich, France) for 20 minutes at 170 ºC (turning the tray around – by 180°– after 10 minutes to ensure homogenous baking). The oven and the oven trays were always the same, the trays were placed at the same level in the oven and the number of biscuits baked was always the same. After cooling, the biscuits were packed in heat-sealed metalized polypropylene bags, stored at room temperature and evaluated after 24 hours.

Instrumental texture measurements

The texture measurements were carried out with a TA-XT.plus Texture Analyser equipped with Texture Exponent software (version 2.0.7.0. Stable Microsystems, Godalming, UK). Three different tests were performed: a breaking strength test and two penetration tests.

Three-point bending test : In this test, the biscuits were broken with the three-point bending probe (A/3 PB). The experimental conditions were: supports 50 mm apart, a 5-mm probe travel distance, a trigger force of 0.196 N and a test speed of 0.5 mm/sec.

Penetration with a cylindrical probe. In this test, the biscuits were penetrated with a cylindrical probe (diameter 3.9 mm) (CYL) up to a distance of 2 mm. The trigger force was 0.05 N and the test speed was 0.5 mm/sec.

Penetration with a spherical probe. In this case, a spherical probe (P/0.5) (SPH) was used to penetrate the biscuits up to a distance of 3 mm, using a trigger force of 0.196 N and a test speed of 0.5 mm/sec. For the three tests, the pre-test speed and the post-test speed was 10 mm/sec.

For sound recording, a Bruel & Kjaer free-field microphone (8-mm diameter) coupled to the TA-XT.plus Texture Analyser was used with the corresponding software (Texture Exponent 32). The microphone was calibrated using a Type 4231 acoustic calibrator (94 dB and 114 dB SPL-1000 Hz) and positioned at a distance of 4 cm and an angle of 45° to the sample (Salvador et al., 2009). Ambient acoustic and mechanical noise was filtered out with a 1 kHz high pass filter. A low pass filter set the upper calibrated, measured frequency at 16 kHz. The data acquisition rate was 500 points per second for both force and acoustic signals. All the tests were performed at room temperature in a laboratory with no special soundproofing facilities. The variations in force as the cylindrical and spherical probes penetrated the biscuit and as the biscuit was pressed until it broke in the three point bend test were recorded in Newton. The sound pressure level was registered in decibels at the same time as the force.

The force-distance curves gave the maximum peak force and distance, initial slope and number of fracture events at different force thresholds and the sound-distance curves provided the maximum sound pressure level, the linear distance and the number of sound events at different thresholds (Table 2). For the instrumental texture tests, each biscuit formulation was prepared twice (two batches) and eight replicates were measured from each batch.

Table 2. Instrumental parameters obtained from the force-distance and sound-distance curves. A number of sound and force peaks were obtained at different threshold levels, as indicated

Test type	Instrumental parameter and identification	Thresholds
3-Point bending	Force at breakage (3P-F.max)	-
	Distance to breakage (3P-Dist)	-
	Slope at max force (3P slope)	-
	Slope at first peak force (3P slope peak)	-
	Number of force peaks (3P fracture)	>1, 0.8, 0.5, 0.3 and 0.1N
	Sound events (3P sound events)	>0.3, 0.2 >0.1dB
Sphere penetration	Maximum Force (Sph max force)	-
	Slope at max force (Sph slope)	-
	Slope at first peak force (Sph slope peak)	-
	Number of force peaks (Sph fracture)	>5, 3, 1, 0.8, 0.5, 0.3 and 0.1N
	Sound events (Sph sound events)	>0.3, 0.2 >0.1dB
Cylinder penetration	Maximum Force (Cyl max force)	-
	Slope at max force (Cyl slope)	-
	Number of force peaks (Cyl fracture)	>1, 0.8, 0.5, 0.3 0.1 and 0.05N
	Sound events (Cyl sound events)	>0.3, 0.2, 0.1 and 0.05dB
	Maximum Sound and Linear distance	-

Sensory texture evaluation

Information about how differences in texture among samples were perceived by consumers was obtained from a Free Choice Profile (FCP) study. A group of 28 consumers (16 women and 12 men) aged from 23 to 65 years evaluated the texture characteristics of the biscuit samples on a 10 cm unstructured line-scale, using their own set of terms. The individual terms were previously obtained by the Repertory Grid method (Tarancón et al., 2013). Each consumer evaluated four samples per session in a standardized test room with separate booths. The samples were coded and served following a balanced design.

Statistical Analyses

Analysis of variance of two factors (fat type and fat content) was used to study the variability among samples of each textural instrumental parameter. Significant differences between individual samples were determined by Fisher's least significant difference (LSD) test ($\alpha = 0.05$). The overall variability in the texture parameters was analysed by principal component analysis (PCA). Finally, a partial least squares regression analysis (PLS) was performed for each consumer in order to assess any possible relationship between the consumers' perceptions and the instrumental parameters. All the calculations were carried out with XLSTAT 2009.4.03 (Addinosoft, Barcelona, Spain).

RESULTS

Instrumental measurements of biscuit texture

The force-distance and sound-distance curves were registered during the three point breaking and penetration tests on each biscuit sample. A total of 38 instrumental parameters were obtained from the curves (Table 2). The parameters without significant variations among the samples according to ANOVA were not considered further. When the values of the parameters at different thresholds were highly correlated (based on a preliminary PCA, not shown), only one threshold was considered. For the final 12 parameters, two-factor ANOVA was used to study the effect of the type and level of fat on each parameter (Table 3).

Table 3. Two –way ANOVA to study the effect of fat level and type on the instrumental texture of biscuits.

Textural parameter	Main effects				Interactions	
	Fat level (A)		Fat type (B)		AxB	
	F-value	P-value	F-value	P-value	F-value	P-value
3P Force at breakage	88.289	< 0.001	5.620	0.007	3.333	0.041
3P Distance to breakage	2.626	0.131	5.939	0.005	0.576	0.718
3P Sound events >0.1dB	0.164	0.692	5.081	0.010	0.484	0.782
Sph Maximum force	16.547	0.002	16.568	< 0.0001	2.226	0.119
Sph Slope at max force	124.556	< 0.001	6.586	0.004	6.556	0.004
Sph N. of force peaks> 1N	12.662	0.004	1.782	0.191	5.238	0.009
Sph N.of force peaks> 0.1N	4.872	0.048	2.980	0.056	3.556	0.033
Sph Sound events>0.1dB	0.860	0.372	3.780	0.027	1.074	0.422
Cyl Maximum Force	188.586	< 0.0001	3.551	0.033	4.772	0.012
Cyl Slope at maximum force	60.292	< 0.001	2.391	0.100	0.308	0.899
Cyl N. of force peaks > 1N	41.966	< 0.001	2.718	0.072	1.722	0.204
Cyl Sound events >0.3dB	13.403	0.003	8.929	0.001	3.075	0.051

In the three-point breaking test, the interaction between the two factors was significant for the breaking force, indicating that the effect of the type of fat depended on the fat level and vice-versa. At the 15.6% fat content the breaking force did not vary significantly between biscuits containing different types of fat (13.4 -17.1 N), but at the lower fat content the breaking force values increased significantly except for the biscuits made with the VEG shortening or the SUN HPMC system (Table 4). At the 10.6% fat content, the VEG shortening sample presented the lowest breaking force (18.2 N) and the SUN XAN biscuit showed the highest value (30.7 N).

For distance to break and number of sound events, only the fat type was significant. Breaking occurred at a greater distance and with more sound events in the samples made with the SUN XAN system than in those containing shortening. With the other gel/oil systems, the values did not vary significantly from those of the shortening biscuits (Table 4).

Table 4. Mean values obtained from the three-point bending test

Fat content (%)	Fat type	Force at breakage (N)	Distance to breakage (mm)	Sound events>0.1dB
10.6	DAI	21.0 bc	0.35de	1.7cd
	VEG	18.2 cd	0.35de	2.0cd
	SUN XAN	30.7 a	0.53a	6.2a
	SUN HPMC	21.0 bc	0.41bcde	2.3bcd
	OLI XAN	25.2 b	0.51ab	4.5abc
	OLI HPMC	23.1 b	0.43abcde	1.1d
15.6	DAI	13.9 d	0.33e	2.1cd
	VEG	13.8 d	0.37cde	1.6cd
	SUN XAN	16.6 cd	0.45abcd	5.5ab
	SUN HPMC	17.1 cd	0.41bcde	3.9abcd
	OLI XAN	13.7 d	0.47abc	3.8abcd
	OLI HPMC	13.4 d	0.35de	2.4bcd

Means in the same column with different letters are significantly different ($p \leq 0.05$) according to Fisher's least significant difference.

In the sphere penetration test, the maximum force values were generally higher in the biscuits made with the DAI shortening than in those made with the oil/gel systems (Table 5). For the slope at maximum force and the number of force peaks higher than 1 N and 0.1 N, the effect of interaction between the factors was significant, indicating that the effect of the type of fat depended on the fat level and vice versa. The slopes at maximum force were generally higher in the biscuits with the lower fat content (10.6%) than in those with the higher level of fat (15.6%). At the 15.6% fat content, the DAI shortening sample presented a significantly higher value than those prepared with the oil/gel systems, whereas at the 10.6% fat content, the biscuits made with the SUN XAN and OLI XAN systems showed the highest values for this parameter.

Table 5. Mean values obtained from the penetration test with a spherical probe

Fat content (%)	Fat type	Maximum Force (N)	Slope at Maximum Force (N.mm^{-1})	Force peaks > 1N	Force peaks > 0.1N	Sound events>0.1dB
10.6	DAI	146.1 a	72.9 bc	5.4 ab	11.9 ab	9.1 b
	VEG	118.3 bcd	57.8 de	7.2 a	16.3 a	12.8 ab
	SUN XAN	119.7 bc	85.7 a	3.9 bcd	8.8 bc	19.5 a
	SUN HPMC	116.9 cd	61.9 d	5.1 bc	12.2 ab	13.7 ab
	OLI XAN	89.6 ef	77.4 ab	3.7 cd	7.2 c	15.0 ab
	OLI HPMC	102.1 cde	62.6 cd	5.1 bc	12.4 ab	17.7 a
15.6	DAI	140.2 ab	59.0 de	2.9 d	12 ab	13.2 ab
	VEG	116.7 cd	50.6 ef	3.8 bcd	13.5ab	8.8 b
	SUN XAN	73.0 f	46.3 f	3.9 bcd	12.1 ab	18.2 a
	SUN HPMC	95.3 def	43.8 f	3.5 cd	12.1 ab	18.0 a
	OLI XAN	73.7 f	42.3 f	5.4 ab	14.1 a	20.3 a
	OLI HPMC	88.8 ef	43.2 f	4.2 bcd	14.5 a	17.5 a

Means in the same column with different letters are significantly different ($p \leq 0.05$) according to Fisher's least significant difference.

Regarding the number of force peaks that occurred during the penetration, at 10.6% fat the number of peaks above 1 N and 0.1 N was higher for the biscuits with shortenings than for those containing the oil/xanthan gum systems. At the higher fat content, the number of peaks above 1 N decreased for the shortenings and the amounts of peaks above 0.1 N increased for the oil/gel systems. Thus, at 15.6% fat the differences among the samples in the number of peaks above 0.1 N were slight.

The number of sound events during penetration was generally higher for the biscuits containing the oil/gel systems.

These results point to clear differences in the internal structure of biscuits made with different types of fat. These differences were more evident at the lower fat content. The biscuits with shortening presented more fractures but fewer sound events while those with xanthan gum presented a lower number of peaks but a high number of sound events. Marzec and Ziółkowski (2007) studied the relation between the internal structure of biscuits and the characteristics of fracture events and showed that biscuits with a higher number of small air cells in their structure have a greater number of fragile fractures but a noticeably lower quantity of acoustic events than biscuits with a high number of high volume pores. Accordingly, the present results suggest that with shortenings the structure formed is a multilayer material with smaller voids and with the oil/xanthan systems it is a structure with larger voids, which are responsible for the higher number of sound events.

In the cylindrical probe penetration test (Table 3), the maximum force value depended on the type and level of fat and the effects of the two interacted. At the 10.6% fat content, the biscuits made with the oil/xanthan systems presented higher maximum force values than the rest. At 15.6% fat, the maximum force values did not vary among the biscuits and were lower than those for the 10.6% fat level (Table 6).

Table 6. Mean values obtained from the penetration test with the cylindrical probe

Fat content (%)	Fat type	Maximum Force (N)	Slope at Maximum Force ($N.mm^{-1}$)	Force peaks > 1N	Sound events>0.3dB
10.6	DAI	53.4b	76.8a	5.5ab	0.7c
	VEG	49.4b	79.1a	6.1a	2.4bc
	SUN XAN	66.5a	63.2abc	5.7ab	7.7a
	SUN HPMC	52.6b	68.5ab	5.6ab	6.0a
	OLI XAN	69.6a	71.2a	6.4a	7.5a
	OLI HPMC	56.1b	60.3abc	5.8ab	1.4c
15.6	DAI	39.0c	48.6bcd	3.5c	0.9c
	VEG	35.0c	44.0cd	4.2c	0.4c
	SUN XAN	33.2c	38.2d	5.7ab	5.1ab
	SUN HPMC	33.4c	32.3d	3.9c	2.4bc
	OLI XAN	34.3c	47.6cd	4.7bc	1.5c
	OLI HPMC	31.5c	29.3d	4.0c	2.4bc

Means in the same column with different letters are significantly different (p≤0.05) according to Fisher’s least significant difference.

For the rest of the force parameters, the ANOVA results showed no significant interaction between the factors as the values only varied significantly with the amount of fat and not with the type of fat. In general, the slope and the number of force peaks above 1 N were higher for biscuits with 10.6% fat than for those with 15.6% fat. In the case of sound events, the variations mainly depended on fat type. The biscuits with the oil/gel systems, especially those with xanthan gum, presented a higher number of sound events than those containing shortenings.

The pattern of differences between cylindrical and spherical penetration were due to the shape and size of the probes. With the cylinder, penetration was the main phenomenon, while the spherical probe produced a combination of compression and penetration of the sample.

Furthermore, both type of penetration essays (cylinder and sphere) proved to be more sensitive than Volodkevich Bite Jaw essay which, in a previous study (Tarancon et al, in press), did not reveal differences in the internal structure of these biscuits being no able to explain the differences in texture acceptability perceived by consumers.

Principle components analysis (PCA) was performed to obtain a simultaneous study of the variations in all the instrumental texture parameters (force and acoustic) of the biscuits containing different types and levels of fat. A two-dimensional plot explained 74.5% of the total variance (Figure 1).

The first dimension (46.0% of the variability) was positively related to the breaking force (3PB test) and the number of fractures and force during cylinder penetration, and negatively related to the number of sound peaks higher than 0.1 N during sphere penetration. This dimension separated the biscuits clearly according to their fat content. The biscuits with the lower fat content, on the right side, presented higher breaking and penetration forces. The biscuits with the higher fat content, on the left side, especially those with shortenings or OLI HPMC, broke easily and showed a low number of fractures during penetration with the cylinder and a high number of fractures (>0.1N) during penetration with the sphere.

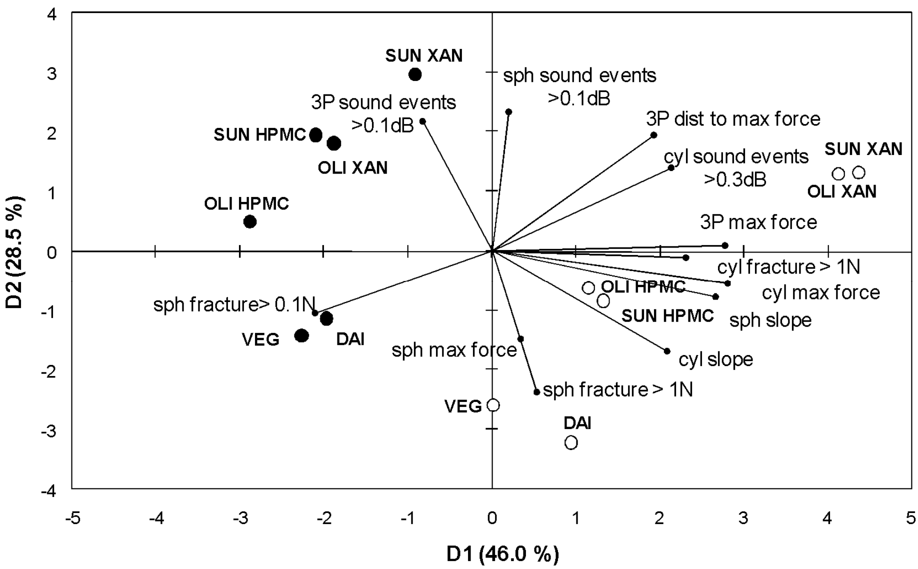

Figure 1. Two-dimension PCA plot of the variations in instrumental texture parameters (force and acoustic) among biscuits containing different types and levels of fat (•: 15.6% fat content; ○: 10.6% fat content). Identification of fat type according table 1. Parameters of 3-Point bending test: Force at breakage (3P max force), Distance to breakage (3P dist to max force), Sound events (3P sound events). Parameters of sphere penetration test: Maximum Force (sph max force), Slope at max force (sph slope), Number of force peaks (sph fracture), Sound events (sph sound events). Parameters of cylinder penetration test: Maximum Force (cyl max force), Slope at max force (cyl slope), Number of force peaks (cyl fracture), Sound events (cyl sound events)

Dimension 2 (28.5% of variability) was positively related to the distance at break and the sound events until break and during penetration. This dimension separated samples according to the type of fat: the biscuits with the oil/xanthan gum systems appeared above and presented higher breaking resistance and more sound events during penetration than samples with shortenings, which appeared below and presented higher force values and more peaks during penetration with the sphere.

Sensory texture of biscuits. Relation with instrumental parameters

The sensory differences among these biscuits were evaluated by consumers using Free Choice Profiling (FCP). The differences in the flavour and texture of the samples were analysed (as reported in a previous paper: Tarancón et al., 2013) and the results showed that the main sensory differences corresponded to texture characteristics. The consumers used a wide variety of terms to describe the differences in texture (hard, hard to chew, easy to chew, crisp, mealy, crumbly, brittle, dry, crunchy, noisy and pasty). As can be observed in the consensus map obtained from the generalised Procrustes analysis (GPA) of the texture terms (Figure 2), dimension 1 explained a high percentage of the variability (79.9%).

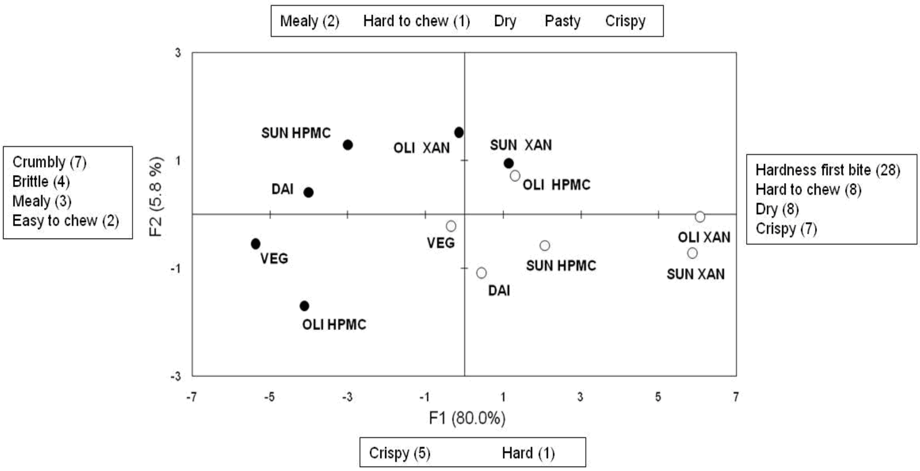

Figure 2. Two-dimension GPA plot of the sensory texture differences among biscuits perceived by consumers. (●: 15.6% fat content; ○: 10.6% fat content). Identification of fat type according table 1

The consumers agreed on the main differences in texture between the samples and described them using similar terms. The positive side of dimension 1 was related to hardness, crunchy or hard to chew and the negative side was mainly linked to mealy, crumby and brittle. According to the GPA plot, the biscuits with a low fat content were perceived as harder, drier and crispier than their high-fat counterparts. Among samples with the same fat level, those with the oil/xanthan gum systems were the hardest, driest and crispest while the biscuits with shortening were perceived as having a mealy, crumbly, brittle texture. The biscuits with the oil/HPMC systems presented a similar texture to the shortening biscuits. The second and subsequent dimensions explained a low percentage of the total variance (<6%) and not much agreement among the consumers, reflecting the individual singularities in perception and in the way to describe them that occur in a complex sensory process such as biscuit consumption (Mobini et al. 2010).

In the present study, the texture attribute intensity data of each consumer were related with the instrumental parameter values using individual partial least squares (PLS) regressions. For each set of terms used by a consumer, the relationship between a texture sensation and each of the instrumental parameters was established according to the standardised coefficients of the PLS regression.

For each sensory term, the instrumental parameters that were found to be related and their frequency are summarised in Table 7. In general, the texture sensation of hardness at first bite was related with the maximum force registered during the bending test and the cylinder penetration test (3P Fmax and Cyl Fmax), the distance where the maximum force at break was registered (3P Dist) and the number of fractures above 1 N during penetration with the cylinder. Hardness at first bite was also related with the number of sound events above 0.3 dB.

Table 7. Physical stimuli and instrumental parameters related with texture sensations

Textural sensation	Instrumental parameter	Physical Stimulus
Hardness first bite (n=28)	3P Fmax (10) CYL Fmax (10)	Force to breakage and penetration
	3P dist (10)	Resistance to brekage.
	CYL F>1N (13)	Number of macrofractures
	CYL s>0,3db (9)	Sound
Hard to chew (or easy to chew) (n=14)	3P Fmax (6)	Force to breakage
	CYL F>1N (9)	Number of macrofractures
Mealy/Crumbly/ Brittle (n=13)	SPH F>0.1N (7)	Number of microfractures
Crispy (n=14)	SPH slope (6) CYL slope (5)	Rate of fracture during penetration
	CYL Fmax (5)	Resistance to penetration
Crunchy (n=5)	CYL F>1N (3)	Number of macrofractures
Dry (n=9)	3P Fmax (5) CYL Fmax (5)	Resistance to breakage and penetration
	CYL F>1N (6)	Number of macrofracures
	CYL slope (5)	Rate of fracture during penetration

Depending on the consumer, one or more parameters were found to be related with instrumental hardness. Although all the consumers related the perception of hardness at first bite with some of these physical stimuli, different consumers did not use the same channels of perception or did not use them all.

For example, Figures 3a and 3b show the PLS regression plots of two consumers. As can be seen in these figures, for consumer a the instrumental parameters involved in the perception of hardness were mainly the resistance to breaking and the sound events during penetration, while for consumer b they were mainly related to the number of macrofractures and the rate of fracture during penetration with the cylinder

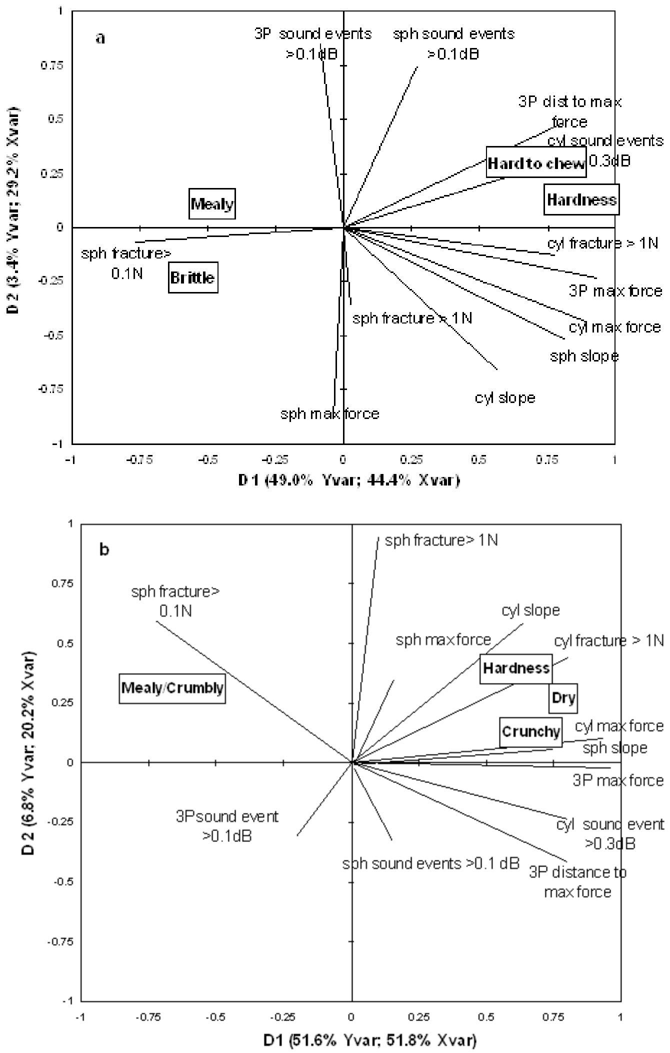

Figure 3. PLS regression plot for two consumers (a and b), relating sensation perceived in the mouth with instrumental parameters. Identification of fat type according table 1. Parameters of 3-Point bending test: Force at breakage (3P max force), Distance to breakage (3P dist to max force), Sound events (3P sound events). Parameters of sphere penetration test: Maximum Force (sph max force), Slope at max force (sph slope), Number of force peaks (sph fracture), Sound events (sph sound events). Parameters of cylinder penetration test: Maximum Force (cyl max force), Slope at max force (cyl slope), Number of force peaks (cyl fracture), Sound events (cyl sound events).

In the case of sound there were clear differences among the consumers, because for about half of them the sound parameters were related to hardness (consumer a), whereas the others (consumer b) did not use the sound parameters at all.

The sensation of hardness perceived during chewing (hard to chew) was mentioned by 14 consumers and was mainly related with the number of force events above 1 N that occurred during penetration with the cylindrical probe and with the maximum breaking force. Unlike the hardness perceived at first bite, hardness perceived during chewing was not related with resistance to breaking. This could be due to the fact that extended chewing is not required for structural breakdown but rather for wetting, assembling and lubricating the particles formed (Lillford, 2011).

Mealy, crumbly and brittle were terms related to the number of microfractures above 0.1 N that occurred during penetration with the spherical probe. For that reason, these three terms can be supposed to be different ways the consumers used to describe the same sensation perceived during the breaking of thin layers of the biscuit material.

Regarding the sensation described as crisp, it should be noted that the most important parameters related with this term were the slopes registered during the cylinder and sphere penetration tests. Hence, this sensation is related with the rate of fracture during penetration, that is to say, with the elastic properties of biscuits. Crispy and crunchy sensations have been widely discussed and the difference between these two texture descriptors is often not clear. In this study, different instrumental parameters were found to be involved in the physical stimuli related with crispness and crunchiness. Booth et al. (2003) stated that the crunchy texture descriptor was mainly related with the quantity of cracks at high forces (Table 7). In the present study, this descriptor was highly correlated with the number of macrofractures that occurred during cylinder penetration.

Nine consumers mentioned dryness as a descriptor, which was related with 3P max, Cyl max, Cyl slope and Cyl >1 N at least five times. Therefore, resistance to breaking and penetration and the number of fractures were perceived as dryness (Table 7). The sensation of dryness shared the same instrumental parameters as that of hardness and the two were very close to each other, as shown in Figure 3a.

In short, the reduction in fat content affected the structure of the biscuits, which presented high breaking and penetration forces and more fractures during cylinder penetration and was perceived as a harder and crunchier biscuit during biting and chewing in the mouth. These effects of the lower fat content were less pronounced for the shortenings than for the oil/gel systems. In the case of the oil/xanthan gum systems, the replacement of saturated fat with vegetable oil made the biscuit more elastic, resistant to breaking and noisier during penetration, increasing the sensation of hardness perceived by the consumers. Furthermore, when the fat content was reduced or the shortening was replaced with oil/gel systems the number of force events (>0.1 N) during sphere penetration was lower and the biscuits were perceived as less mealy, crumbly and brittle. The vegetable shortening provided the greatest number of force events (>0.1 N) and this sample was mealier and crumblier than the other biscuits. The oil/HPMC systems (olive oil at the higher fat content and both sunflower and olive oil at the lower fat content) conferred similar mechanical and acoustic properties to those provided by the shortening fats, leading to biscuits with similar texture properties in the mouth.

CONCLUSIONS

Fat plays an important role in the structure of biscuits and thus in their mechanical properties. Changes in texture were observed when the fat content was reduced and also when saturated fat was replaced with oil/gel systems. The sensory perception of texture can be understood through measurement of the mechanical and acoustical phenomena that occur when samples are subjected to different deformation tests. Although the consumers used similar terms to describe the main differences in texture of the biscuits, some individual differences in perceptions and in the way to describe them were observed. Replacing saturated fat is critical in biscuits with a low fat content, as the changes in texture were more pronounced in biscuits with a 10.6% fat content than in biscuits with a 15.6% fat content. The oil/xanthan gum systems made the biscuits more elastic, resistant to breaking and noisy during penetration, while the oil/HPMC systems conferred similar mechanical and acoustical properties to those provided by the shortenings. Hence, the replacement of saturated fat by vegetable oil (olive or sunflower)/HPMC may be proposed as a good alternative to produce healthier biscuits.

ACKNOWLEDGEMENTS

The authors wish to thank the Spanish Ministry of Science and Innovation (AGL 2009-12785- C02-01 for the financial support and for Tarrega's contract within the Juan de la Cierva Programme. The authors also wish to thank The Dow Chemical Co. (Michigan, USA); Cargill, (Martorell, Spain) for providing free samples of the ingredients and to Gabriela van Best for her contribution in samples preparation and instrumental texture measurement.

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CAPÍTULO 5

Sensory properties and acceptance of biscuits made with olive and sunflower oil

Enviado a la revista *Food and Bioprocess Technology*

SENSORY PROPERTIES AND ACCEPTANCE OF BISCUITS MADE WITH OLIVE AND SUNFLOWER OIL

P. Tarancon, A. Salvador, T. Sanz, S. Fiszman and A. Tárrega

ABTRACT

The aim of this study was to evaluate consumer acceptability of biscuits when saturated fat was replaced by olive or sunflower oil and to determine the sensory characteristics responsible for changes in acceptability. Ninety seven consumers evaluated the acceptability of six biscuit samples varying in the fat source (dairy shortening, olive oil and sunflower oil) and fat content (10.6% and 15.6%). Using Check All That Apply test, consumers also evaluated sensory properties of biscuits. Results indicated that the replacement of saturated fat by vegetable oils had an effect on biscuit acceptability which depended on biscuit fat content. According to biscuits' acceptability data, three different groups of consumers were identified. By using a multiple factor analysis, the relationship among sensory CATA data and acceptability of each cluster explained the different preference patterns of consumers. For most of consumers preference was related to attributes "crispy", "easy to chew" and "biscuit flavor" which, for one group were perceived in shortening biscuits and, for another in both olive and shortening biscuits. However, for the third group of consumers, preference was only related with flavour attributes like "roasted flavour" or "biscuit flavour" that were perceived in vegetable oil biscuits which were the preferred biscuits and, on the contrary, shortening biscuits were disliked and perceived as having an "off flavour".

Keywords: Consumers' acceptability, biscuits, drivers of liking.

INTRODUCTION

The use of vegetable oils as a replacement of solid fats in biscuits is an alternative to make products with a healthier fatty acid profile. However, due to the fact that fat is one of the principal ingredients, reducing the fat content or replacing fat with other ingredients has a considerable impact on the mechanical properties which in turn, might affect sensory perception and, thereby have important implications for consumer acceptance of such products (Baltsavias, Jurgens & van Vliet, 1999; Zoulias et al., 2002; Rodríguez-García et al., 2012).

In the development of such new products, food companies require information about how consumers perceive the sensory characteristics of the product and which sensory attributes drive the acceptability in order to design food products that match consumer expectations (Guinard, et al., 2001; Ten Kleij & Musters, 2003). Usually, the study of the relationship between the acceptability and the sensory characteristics of a product is carried out by comparing descriptive analysis data and consumer data, although the best way to understand consumer preferences is using consumer data. In this sense, the use of check-all-data-apply questions (CATA) can be useful to gather information about consumers' perception of food products by the selection of the terms from a list that consumers consider appropriate when describing a product.

Previous studies have shown that the reduction of fat or its replacement with a more unsaturated fat affects the technological or sensory characteristics of different products, mainly of those in which fat is one of the major components of the formulae (Morales-Irigoyen, et al., 2012). When the fat content of a food product is reduced, it is interesting to know to which extent consumers perceive the changes induced in the product and, eventually, if those changes affect the acceptability of the product. For instance, a partial replacement (20%) of pork backfat with olive oil in fermented sausages resulted in low-fat sausages with an unacceptable appearance (Muguerza, et al., 2003). Therefore, the type or amount of fat may produce significant changes in the physical properties of food products.

A previous study demonstrated that the use of vegetable oil (olive or sunflower oil) and/or fat reduction in biscuits result in changes in the mechanical and acoustical responses of biscuits that consumers perceive as differences in hardness, crunchiness, mealiness and cumbliness. (Tarancon et al., in press). Hence, it would be interesting to evaluate the acceptability of biscuits with an improved fatty acid profile by consumers, and which sensory changes might be involved in that acceptability.

Therefore, the aim of this study was to evaluate consumer acceptability of biscuits when saturated fat was replaced by olive or sunflower oil and to determine the sensory characteristics responsible for changes in acceptability.

MATERIALS AND METHODS

Samples description

Biscuit samples varied in the type of fat, i.e., a dairy shortening, an olive oil/gel system and a sunflower oil/gel system, and in the fat content, i.e., low fat content (10.6%) and high fat content (15.6%). The shortening used was a dairy shortening (Vandemoortele, Diexpa ref. 402684, Valencia, Spain) commonly used in the manufacture of biscuits. The oil/ gel systems were prepared according to a procedure described in a previous work (Tarancon et al., in press) with sunflower oil (Coosol, Jaén, Spain) or olive oil (Fontoliva, Jaén, Spain) and with the thickener hydroxypropyl methylcellulose ((HPMC), Methocel Food Grade K4M FG, The Dow Chemical Co., Midland, Michigan, USA).

The amounts of the rest of ingredients in the formulation were kept constant (dough weight basis): soft wheat flour 57.5% (Harinas Segura, S.L., Valencia, Spain; composition data provided by the supplier: 11% protein, 0.6% ash;

alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), sugar 17% (Azucarera Ebro, Madrid, Spain), skimmed milk powder 1% (Central Lechera Asturiana, Spain), salt 0.6%, sodium bicarbonate 0.2% (A. Martínez, Cheste, Spain), and ammonium hydrogen carbonate 0.11% (Panreac Quimica, Barcelona, Spain). Fat shortening or vegetable oil systems were added to achieve 12.5 and 8.5% fat content in dough and a final fat content of 15.6 and 10.6% in biscuits, respectively. The water added in each formulation ranged from 111 g for low fat content biscuits to 45 g for high fat biscuits. In the formulations with the oil/gel system, glycerol (1.8%) (Panreac Quimica, Barcelona, Spain) was also added to control the water activity.

Biscuit preparation

The shortening or the oil/gel system, sugar, milk powder, leaving agents, salt, water and glycerol (added only in formulations with the oil/gel system) were mixed in a mixer (Kenwood Ltd., U.K) for 1 min at low speed (60 rpm), the bowl was scraped down and the mixture was mixed again for 3 min at a higher speed (255 rpm). The flour was added and mixed in for 20 s at 60 rpm, then mixed for a further 40 s at 60 rpm, after having scraped down the bowl once more. The dough was sheeted with a sheeting machine (Parber, Vizcaya, España) and moulded into pieces of 52 mm in diameter×3.4 mm in thickness. Twenty biscuits were placed on a perforated tray and baked in a conventional oven (De Dietrich, Basingstoke, UK) for 20 min at 170 ºC (10 minutes each side of the tray to ensure homogenous baking). The oven and the oven trays were always the same, the trays were placed at the same level in the oven and the number of biscuits baked was always the same. After cooling, the biscuits were packed in heat-sealed metalized polypropylene bags, stored and evaluated after 24 h.

Consumer test

Ninety seven consumers participated in the study. For each sample, consumers had to score the acceptability using a nine-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”). After that consumers were asked to answer a CATA question comprising 22 sensory attributes. These descriptors were selected based on results from a previous study in which 28 consumers generated their own set of terms by using the Repertory Grid method (Tarancon et al., in press) and were: “crispy”, “hard”, “dry”, “easy to swallow”, “fat mouthfeel”, “hard to chew”, “easy to chew”, “crumbly”, “brittle”, “mealy”, “soft”, “butter flavour”, “biscuit flavour”, “roasted flavour”, “tasteless”, “off-flavour”, “not very sweet”, “rancid flavour”, “unpleasant aftertaste”, “very sweet”, “vanilla flavour” and “artificial flavour”. Each consumer was asked to check the terms that he or she considered appropriate to describe the biscuit sample. The evaluations were carried out in a standardized test room (ISO 2007); samples biscuits were served in white plastic dishes and they were presented monadically following a Williams design (McFie et al., 1989).

Data analysis

The individual acceptance responses of consumers to each product were analysed by a preference map using a PCA on the correlation matrix of consumers’ individual acceptance data (MacFie & Thompson, 1998), and the results were expressed as a scatter plot of samples and individual consumers in relation to the first two principal dimensions.

A hierarchical cluster analysis was performed on acceptability data in order to identify groups of consumers with similar preference patterns, and Euclidean distances and Ward’s aggregation method were considered. Then, analysis of variance of two factors (fat type and fat content) was used to study the variability of the preference among samples in each cluster. Significant differences between individual samples were determined by the Least

Significant Difference (LSD) of Fisher test (α = 0.05). The non-parametric Cochran's test analysis of variance was performed for each descriptor to evaluate if the CATA questions were able to detect differences in consumer perception of the biscuits. Overall variability in the frequencies of mention of significant attributes was analysed by using a Correspondence Analysis (CA). Finally, in order to assess the relationship between CATA responses and biscuit acceptability scores, a Multiple Factor Analysis (MFA) was performed on the frequency of mention of the CATA question for each cluster. All calculations were carried out with XLSTAT 2009.4.03 (Addinsoft, Barcelona, Spain).

RESULTS AND DISCUSSION

Biscuit acceptability: influence of individual preferences

The acceptability of biscuit samples was evaluated by consumers. A preference map was obtained, explaining 59.8% of the overall variability of the acceptability data (Figure 1).

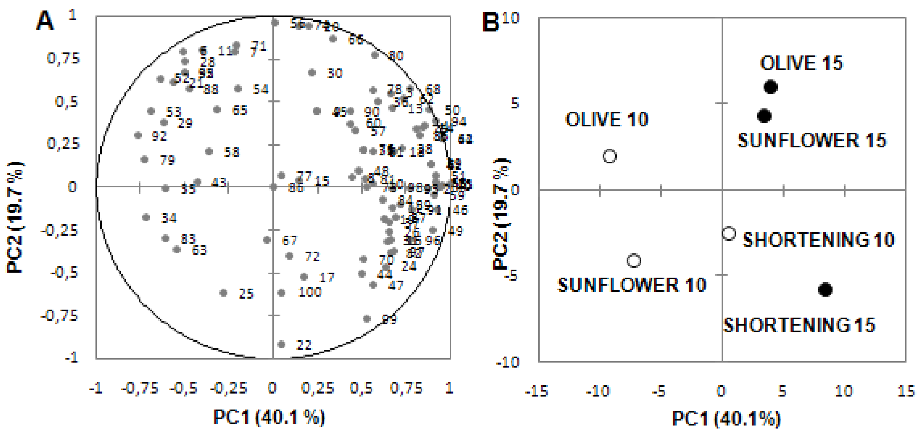

Figure 1. Consumers preference map of biscuits: (A) consumers representation and (B) samples representation.

The first dimension accounted for 40.1% of the variability and separated the samples according to biscuit fat content; the high fat content biscuits being displayed on the right side of the plot (Figure 1B). Consumers were mainly scattered on the edges of the right and left side of the plot, thus revealing heterogeneity in consumer preferences. According to that result, and to study the differences in the acceptability among samples for each group of consumers, a hierarchical cluster analysis was carried out. Three groups of consumers with different preference patterns were identified. Cluster 1 was made up of 23 individuals, cluster 2 of 47 individuals and cluster 3 of 27 individuals. For each cluster, two-way ANOVA was used to study the effect of the fat type (shortening, olive oil and sunflower oil) and the fat content (low fat content: 10.6% and high fat content: 15.6%) on biscuit acceptability (Figure 2).

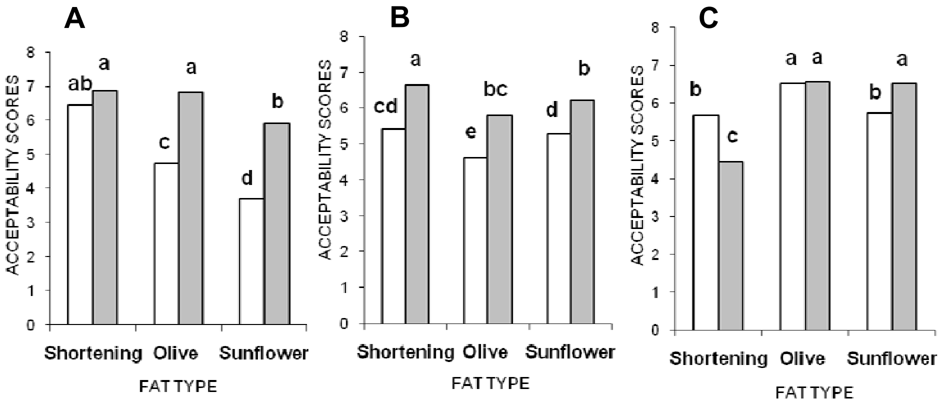

Figure 2. Biscuits acceptability scores for cluster 1 (A), cluster 2 (B) and cluster 3 (C). White: 10,6% fat content biscuits; Grey: 15,6% fat content biscuits. Scores not sharing letters were significantly different (p≤ 0.05) according to Fisher test.

For cluster 1, ANOVA results showed that the interaction between the two factors was significant (F =11.81, P < 0.0001), indicating that the effect of the fat type on acceptability depended on the fat level and vice versa. At high fat content, the most preferred biscuits were those with olive oil and shortening.

Consumers found shortening biscuits at low fat content as acceptable (no significant differences) as shortening biscuits at high fat content, while they disliked the olive and sunflower oil biscuits at low fat content (Figure 2A).

In the case of consumers from cluster 2, the acceptability scores varied significantly among samples, and both the fat type and the fat content had a significant effect (F= 14.22, P < 0.0001; F=77.59, P < 0.0001, respectively). The consumers of this group, preferred shortening biscuits to vegetable oil biscuits, and acceptability scores decreased when the fat content decreased for shortening samples as well as for vegetable oil biscuits (Figure 2B). Thus, they liked the shortening biscuits at high fat content the most; followed by olive and sunflower oil biscuits (both at high fat content). However, they scored olive oil biscuits at low fat content to be the least acceptable ones.

Finally, for consumers of cluster 3, acceptability scores showed a significant interaction between fat type and fat content (F =12.02, P < 0.0001), thus the effect of the fat type was different depending on the fat content. In this group, consumers clearly preferred olive oil biscuits (at both fat content) than shortening ones and shortening biscuits were the least preferred. Sunflower oil biscuit at high fat content also showed high acceptability (Figure 2C).

Differences among samples described by CATA

According to the non-parametric Cochran's test, significant differences were found in the frequencies of 17 out of the 22 terms of the CATA question used to describe samples suggesting that this type of question was able to detect differences in consumers' perception of the biscuits.

However, no significant differences were found for the terms “brittle”, “very sweet”, “unpleasant aftertaste”, “mealy” and “soft”. Besides, there were 4 descriptors (“crumbly”, “rancid flavor”, “vanilla flavour” and “artificial flavor”) that were significant but their frequencies of mention for any sample were below 10, so they were not further considered.

Hence, 13 descriptors were finally considered; 7 of those terms were related with textural characteristics of the biscuits like “crispy”, “hard”, “dry”, “easy to swallow”, “fat mouthfeel”, “hard to chew” and “easy to chew”; and the other 6 were related with flavour such as “butter” “flavour”, “biscuit flavour”, “roasted flavour”, “tasteless”, “off-flavour”, and “not very sweet”.

Correspondence Analysis (CA) was performed on the 13 terms considered (Figure 3). The first two dimensions of the CA plot explained 95.5% of the overall variability of the data set accounting the first and second dimension for 76.84% and 18.69% of the overall variability, respectively.

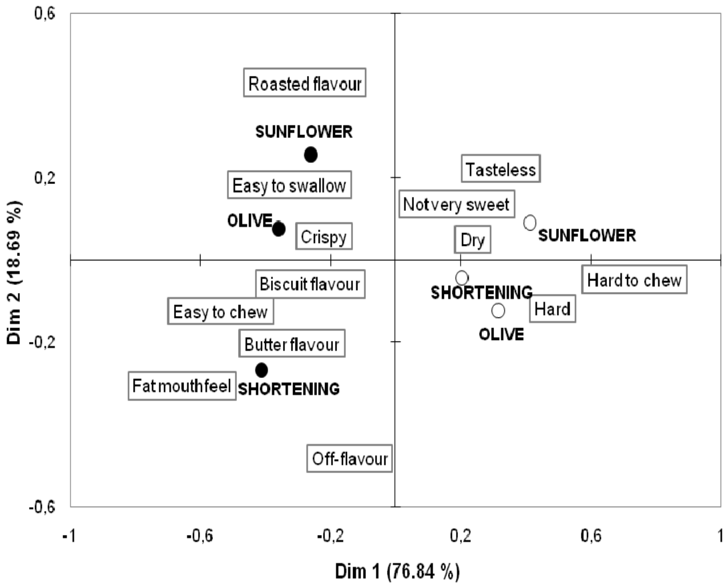

Figure 3. Correspondence Analysis of CATA question data for evaluation of biscuit with different fat type and content (○symbols: 10.6% fat content biscuits; ● symbols: 15.6% fat content biscuits)

As it is shown in the CA plot, in general, terms like “dry”, “tasteless” and “not very sweet” were associated with one another and so did “hard” and “hard to chew” being low fat content samples linked with all these terms. On the other hand, it seems that, in general, the perception of high fat content biscuits was slightly different (in comparison to low fat content samples) due to the different fats used in these formulations as different descriptors were associated with those samples. “Crispy”, “easy to swallow”, “biscuit flavour”, “easy to chew”, “butter flavour” and “fat mouthfeel” were associated to one another and high fat content shortening and olive biscuits were considered as mainly having these properties. Furthermore, “roasted flavour” displayed alone in the plot and high fat content sunflower biscuit was considered as having that property. The term “off-flavour” also appeared alone in the bottom of the plot and high fat shortening 15 was the sample described with this attribute.

Relationship between consumers’ acceptability of biscuits and CATA results.

In order to understand which sensory properties were related with acceptability, the sensory data from CATA question was studied in combination with consumers’ acceptability data. For each group of consumers, it might be possible that consumers used the terms of the CATA question differently indicating possible differences in the perception of biscuits among clusters, and eventually, that those differences were traduced in differences in acceptability. Therefore, Multiple Factor Analysis (MFA) was carried out considering CATA counts for each cluster and their corresponding biscuits’ acceptability scores (Figure 4).

The two first dimensions of the MFA of cluster 1 accounted for 88.2% of the overall variability of the experimental data explaining the first dimension 78.24% of variability (Figure 4A). Consumers of this group liked the most the olive oil and shortening biscuits at high fat content that were perceived as “easy to chew”, “easy to swallow”, “crispy” and as having “biscuit flavour”. On the other hand, they disliked the sunflower and olive oil biscuits at low fat content that they considered “hard to chew”, “hard”, “tasteless” and “not very sweet”.

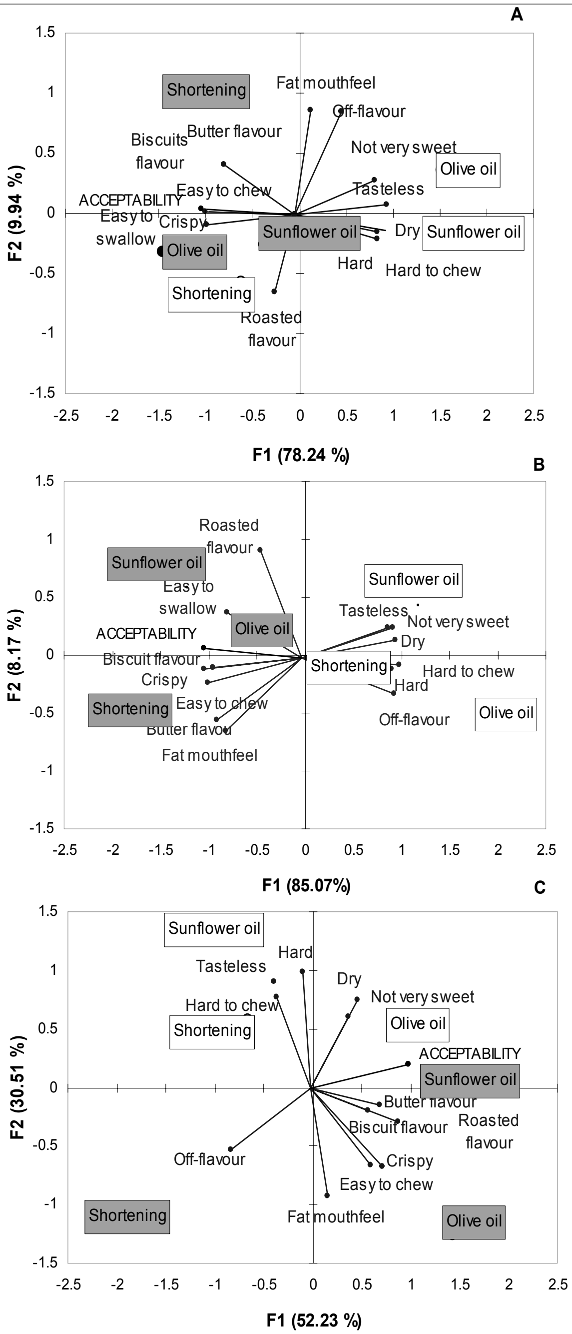

Figure 4. Multiple factor analysis using acceptability scores and CATA data for consumers of cluster 1 (A), cluster 2 (B) and cluster 3 (C); White: 10,6% fat content biscuits; Grey: 15,6% fat content biscuits

The MFA of the cluster 2 accounted 93.25% of the overall variability (Figure 4B) representing 85.07 and 8.17% of the variance for the first and second dimension, respectively. In this group of consumers the biscuits' acceptability was high for biscuits made with shortening that were perceived as "crispy", "easy to chew" and as having "biscuit flavour". They disliked the most the olive oil biscuits at low fat content that were perceived as having "off-flavour". These consumers also disliked sunflower oil at low fat content that were perceived as "tasteless" and "not very sweet". Furthermore, both vegetable oil biscuits were found as being "hard" and hard to chew"

The MFA of the cluster 3 accounted 82.74% of the overall variability (Figure 4C). In this case both first and second dimensions (52.23 and 30.51%, respectively) were required to explain the overall variability. Unlike that occurred for the cluster 1 and 2, where first dimension explained almost all the variability and the textural and flavour terms were well correlated, in the case of cluster 3 consumers differentiated to a higher extent textural and flavour characteristic of samples. According to the MFA plot, the first dimension was related with flavour and the second dimension separated samples according to their differences in texture.

For this group of consumers, the acceptability was positively related with "butter flavour", "roasted flavour" and "biscuit flavour" that they perceived in sunflower and olive oil biscuits at high fat content. For these consumers the butter flavour, the roasted flavour and the biscuits flavour seem to describe the same sensations as these descriptors are close to each other (Figure 4A). In addition, olive oil biscuits at 15.6% fat content were perceived as "crispy" and "easy to chew". Furthermore, consumers of this cluster disliked the most the shortening biscuits at high fat content which were perceived as having "off-flavour". It should be noticed that for the other two clusters, the off-flavour sensation was associated to olive oil biscuits. Moreover, consumers of this group noticed differences in the textural characteristics of biscuits (related to dimension 2) but those differences did not affect acceptability as it seems that the flavour properties were the sensory characteristics most linked to acceptability. On the contrary for consumers of cluster 1 and 2, texture and flavour attributes were correlated and both related to acceptability. Consumers of cluster 3 seemed to have different drivers of liking. That is to say that, while the drivers of liking of consumers of cluster 1 and 2 were easy to chew, crispy and biscuit flavour and the drivers of disliking were hard to chew, in the case of consumers of cluster 3, the drivers of liking were butter flavour, roasted flavour and biscuit flavour and the drivers of disliking were off-flavour.

CONCLUSIONS

Changes in biscuit acceptability when replacing saturated fat by vegetable oils depend on biscuit fat content. In low fat biscuits (10.6%) saturated fat replacement imply in general a decrease in acceptability but when the fat content is higher (15.6%) the replacement is possible without significant changes in acceptability. Furthermore, acceptability of biscuits with different fat source and content varies among consumers. Combining CATA data with acceptability allows explaining the different preference patterns of consumers. For most of consumers (72%) preference is related to attributes “crispy”, “easy to chew” and “biscuit flavor”. For a group (48% of consumers) shortening biscuits present theses attributes and therefore they are the most preferred, while for the other group (24%) both olive oil and shortening biscuits at high fat content are those having these attributes and then the most preferred biscuits. On the contrary, for a third group of consumers (28%) only flavour attributes affect acceptability, and they prefer vegetable oil biscuits because of its roasted and biscuit flavour than shortening biscuits which they perceive as having an off flavour. According to the results, oil/gel systems made with olive oil is a good option to be considered in the development of biscuits with a healthier fatty acid profile.

ACKNOWLEDGEMENTS

The authors wish to thank the Spanish Ministry of Economy and Competitiveness (AGL 2009-12785- C02-01) for the financial support and for Tarrega's contract within the Juan de la Cierva Programme. The authors also wish to thank The Dow Chemical Co. (Michigan, USA) for providing free samples of the ingredients.

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CAPÍTULO 6

Consumers' hedonic expectation and healthiness perception of biscuits made with olive or sunflower oil

Enviado a la revista *Food Research International*

CONSUMERS' HEDONIC EXPECTATIONS AND HEALTHINESS PERCEPTION OF BISCUITS MADE WITH OLIVE OIL AND SUNFLOWER OIL

P. Tarancon, S.M. Fiszman, T. Sanz, A. Tárrega

ABSTRACT

Vegetable oils can be used as an alternative to solid fats to produce biscuits with a healthier fatty acid profile. The aim of this work was to study how consumers perceived the information about fat on biscuit labels when olive oil or sunflower oil was used instead of a saturated fat and how much the replacement affected acceptability. Six samples of biscuits were prepared, varying in fat source (dairy shortening, olive oil and sunflower oil) and in fat content (10.6 and 15.6%). Biscuit labels were designed to include the claims "with olive oil", "with sunflower oil" or "low in saturated fat" and nutritional facts tables with the respective values that corresponded in each case. Consumers (n=100) evaluated their liking for the samples and perception of their healthiness under three conditions: blind (the biscuit was provided), expected (the label was provided) and informed (both biscuit and label were provided). In general, consumers expected that they would like the olive and sunflower oil biscuits with low fat contents the most, although when they tasted the biscuits these samples obtained the lowest liking scores. Thus, they did not associate a low-fat vegetable-oil biscuit with a decrease in sensory properties compared to its high fat counterpart. Furthermore, when information on the fat source was provided the consumers seemed to attach less importance than they should have to the total fat level. Although the fat source claim ("with olive oil" or "with sunflower oil") and the nutritional claim ("low saturated fat content") included on

the labels increased the consumers' liking scores, eventually both the sensory quality of the samples and the information provided affected the actual liking for the samples. However, the perception of the biscuits' healthiness was based on the label information alone and the hedonic characteristics of the samples did not affect it.

Keywords: Biscuits, vegetable oil, label information, consumers' expectation

INTRODUCTION

When developing or improving food products, companies should understand the factors that affect consumer preferences in order to ensure the product's success in the marketplace. Consumer responses to foods depend on the interaction of several factors of different kinds (Jaeger, 2006; Köster, 2007). These factors are divided into three categories: food properties, individual or consumer characteristics and the context of food consumption (Shepherd, 1989). The sensory quality of the product is crucial for its acceptance but other non-sensory characteristics like the label, packaging or price can influence it. Consequently, knowing how consumers perceive the information on the label can be especially relevant for understanding their response to new healthy products. The level of the consumer's nutritional knowledge can also influence his/her response to nutritional information on the product and willingness to purchase it (Ares, Giménez & Gámbaro, 2008). It has been observed that motivated consumers can translate an assumed health benefit into a better liking for a new product and also that, even if liking remains unaltered, the purchase interest may increase if a health benefit is expected. Thus, either the hedonic response or a behavioural disposition, or both, could be altered by various combinations of health messages and sensory experiences (Kähkönen, Tuorila, & Rita, 1996; and Tuorila, Andersson, Martikainen, & Salovaara, 1998).

The methodology of expectations is a realistic approach that takes into account how much consumers like the sensory properties of a product and the preconceptions they have about the distinctive features of the product and its sensory characteristics (Torres-Moreno, Tárrega, Torrescana & Blanch, 2012). Before consumers taste a particular food product they usually have an idea of what its sensory characteristics might be (sensory expectations) and how much they will like or dislike it (hedonic expectations), therefore expectations can be defined as a pretrial belief about a product (Olson & Dover, 1979, Villegas, Carbonell, & Costell, 2008; Torres-Moreno, Tárrega, Torrescasana, & Blanch, 2012). These expectations are created by the consumers' previous experiences with the product or by the opinion they have about its packaging, nutritional characteristics or composition (Varela, Ares, Giménez, & Gámbaro, 2010; Bruhn et al., 1992). When the product is chosen and then tasted, the expected sensory and hedonic characteristics are compared with the real ones, leading to confirmation or disconfirmation (Deliza & McFie, 1996). Subsequent confirmation or disconfirmation can lead to either repeat consumption or rejection of a product (Villegas, Carbonell, & Costell, 2008). According to Tuorila, Cardello and Leisher (1994), hedonic expectations and the immediate information about a product (label) combine to determine actual liking and therefore, possibly, affect consumer choices. Previous studies have shown that the effect of expectations created by nutritional information on the consumers' responses can differ depending on multiple factors like the product itself, how information is delivered to the consumer or how it is included on the label. Carrillo, Varela and Fizsman (2012) found that the information on biscuit packaging had a strong influence on the consumers' perceptions and that the consumer's familiarity with each product was an important factor. They also observed a clear impact of nutrition claims for the biscuits and that biscuits with too much information on their packaging were perceived negatively and with distrust. According to Saba et al. (2010), verbal health claims and pictorial representations referring to the naturalness and medical uses of food had different impacts on the consumers' perception of the healthiness of the product as well as on their likelihood of buying it. However, Kähkönen, Tuorila and Lawless (1997), in their study of consumers' expectations of yogurt, found that health-related information about the product was not a salient factor for consumers in this case, probably because yogurt was already perceived as a healthy product compared to others. Thus, in each particular case it is necessary to study how consumers' expectations affect acceptability in order to understand consumer responses to a new product feature.

Biscuits are one of the most popular bakery items in which fat plays a decisive role. Some important sensory characteristics are strongly dependent on the fat type and content, as fat imparts shortening, richness and tenderness, and also improves mouthfeel and flavour delivery (Pareyt & Delcour, 2008; Hadnadev, Dokić, Hadnadev, Pajin, & Krstonošić, 2011). For bakery companies, developing biscuits with a low fat content and using fats with a healthier fatty acid profile can be a good opportunity to launch new products on the market. Decreasing the saturated fat intake and increasing the unsaturated fat intake helps to maintain healthy cholesterol levels and, in consequence, to decrease the risk of coronary heart disease. According to dietary guidelines, reducing the saturated fat content of the biscuit by using vegetable oils, which have considerably lower saturated fatty acid content, would be an interesting option for obtaining healthier biscuits. Olive oil is characterized by high amounts of monounsaturated fatty acids, as well as by its high content in antioxidant agents, which are able to scavenge free radicals and afford adequate protection against peroxidation (Visioli, Poli, & Gall, 2002). Unlike olive oil, which is common in the daily diet of a large part of the Mediterranean population, sunflower oil is consumed in large quantities all over Europe and is characterized by its high polyunsaturated fatty acid content. In a product formulated with vegetable oils instead of saturated fat, information about this improvement can be delivered to the consumer through the label in different ways. The label can include the claim that the product is made “with olive oil” or "with sunflower oil". In the nutritional composition table the fatty acid profile changes to a higher amount of monounsaturated and polyunsaturated fatty acids. Also, when the sum of saturated fatty acids and trans-fatty acids in the product does not exceed 1.5 g per 100 g and when those fatty acids provide less than 10 % of the energy the label can claim that the product is "low in saturated fat". How consumers perceive and understand this information and the expectations it creates in them will determine the success of such a product. According to Eckel et al. (2009), consumer awareness about dietary fat is increasing but knowledge regarding food sources of saturated and trans fats is relatively low among American consumers. There are studies about how fat content affects consumers' perceptions of many types of foods, but not much information on how specific information about the source of the fat or the fatty acid profile of the product is perceived. It seems that, in general, consumers associate reduced-fat products with a reduction in taste quality, but this effect depends on the type of product studied (Lloyd, Paisley, & Mela, 1995; Norton, Fryer & Parkinson, 2013). According to Tuorila, Cardello and Leisher, (1994), hedonic expectations of fat-free foods are generally lower than for regular-fat foods and are controlled by familiarity with the product and an individual's "dietary style". In biscuits, there is no information about how consumers perceive the fat reduction and improved fatty acid profile when using olive oil or sunflower oil instead of saturated fat.

The aim of this work was to study how consumers perceived the information concerning the content and source of fats in biscuits and how much it affected their liking for the product.

MATERIALS AND METHODS

Samples

Six different biscuits formulations were studied. The biscuit samples varied in the type of fat – a dairy shortening, an olive oil/gel and a sunflower oil/gel – and fat content – low (10.6%) or high (15.6%). The shortening was a dairy shortening (Vandemoortele, Diexpa ref. 402684) commonly used in the manufacture of biscuits. The oil/ gel systems were prepared according to a procedure described in a previous paper (Tarancon et al., 2012), using sunflower oil (Coosol, Jaén) or olive oil (Fontoliva, Jaén) and the thickener hydroxypropyl methylcellulose (HPMC) (Methocel Food Grade K4M FG (E464), The Dow Chemical Co., Midland, Michigan, USA).

The amounts of the other ingredients in the formulation were kept constant (dough weight basis): soft wheat flour 57.5% (Belenguer, S.A., Valencia; composition data provided by the supplier: 11% protein, 0.6% ash; alveograph parameters P/L=0.27, where P=maximum pressure required and L=extensibility, and W=134, where W=baking strength of the dough), sugar 17% (Azucarera Ebro, Madrid, Spain), skimmed milk powder 1% (Central Lechera Asturiana, Spain), salt 0.6%, sodium bicarbonate 0.2% (A. Martínez, Cheste, Spain), and ammonium hydrogen carbonate 0.11% (Panreac Quimica, Barcelona, Spain). In the formulations with an oil/gel system, glycerol (1.8%) (Panreac Quimica, Barcelona, Spain) was also added to control water activity. The characteristics of each biscuit sample and its corresponding label information are described in Table 1.

Table 1. Fat characteristics and label information for the six biscuits samples

Sample	Fat		Information provided in the label	
	Source	Content (%)	Claim	Nutritional information content (values per 100 g biscuit)
Shortening 10	Shortening	10.6	-	Energy= 367 kcal; Proteins=6 g; Carbohydrates=63.4 g, sugars=11.5; Fat=10.6g, saturated=6.8g, monounsaturated=2.7g, poliinsaturated=0.8g, trans= 0.3g
Shortening 15	Shortening	15.6	-	Energy= 413 kcal; Proteins=5.7 g; Carbohydrates=63.4 g, sugars=11.5; Fat=15.6g, saturated=10g, monounsaturated=3.9g, poliinsaturated=1.3g, trans= 0.4g
Olive 10	Olive oil	10.6	*"with olive oil"* and *"low in saturated fat"*	Energy= 367 kcal; Proteins=6 g; Carbohydrates=62.3 g, sugars=11.3; Fat=10.6g, saturated=1.6g, monounsaturated=8g, poliinsaturated=1g, trans= 0g
Olive 15	Olive oil	15.6	*"with olive oil"*	Energy= 413 kcal; Proteins=6 g; Carbohydrates=62.3 g, sugars=11.3; Fat=15.6g, saturated=2.2g, monounsaturated=11.7g, poliinsaturated=1.7g, trans= 0g
Sunflower 10	Sunflower oil	10.6	*"with sunflower oil"* and *"low in saturated fat"*	Energy= 367 kcal; Proteins=6 g; Carbohydrates=62.3 g, sugars=11.3; Fat=10.6g, saturated=1.4g, monounsaturated=2.5g, poliinsaturated=6.7g, trans= 0g
Sunflower 15	Sunflower oil	15.6	*"with sunflower oil"*	Energy= 413 kcal; Proteins=6 g; Carbohydrates=62.3 g, sugars=11.3; Fat=15.6g, saturated=2g, monounsaturated=3.7g, poliinsaturated=9.8g, trans= 0g

Biscuit preparation

The shortening or oil/gel system, sugar, milk powder, leaving agents, salt, water and glycerol (added only in formulations with oil/gel system) were mixed in a mixer (Kenwood Ltd., UK) for 1 min at low speed (60 rpm). The bowl was scraped down and the mixture was mixed again for 3 min at a higher speed (255 rpm). The flour was added and mixed in for 20 s at 60 rpm then the mixture was mixed for a further 40 s at 60 rpm after scraping down the bowl once more. The dough was sheeted with a sheeting machine (Parber, Vizcaya, España) and moulded into pieces of 64 mm in diameter×3.4 mm in thickness.

Twenty biscuits were placed on a perforated tray and baked in a conventional oven (De Dietrich, France) for 20 minutes at 170 ºC (turning the tray 180° after 10 minutes to ensure homogenous baking). The oven and the oven trays were always the same, the trays were placed at the same level in the oven and the number of biscuits baked was always the same.

Nutritional knowledge questionnaire

In order to assess the consumers' nutrition knowledge concerning fats, they were ask to answer a series of questions extracted from “the general nutrition knowledge questionnaire for adults” proposed by Parmenter and Wardle (1999). In the present work, only the questions that were related with fat in the diet were selected, translated and adapted for a Spanish population. The survey was made up of 12 questions which included a total of 27 items. The questions were classified in three sections: Fat content in food products (7 items), saturated fat in food products (10 items) and fatty acid types and fat sources (10 items). The questionnaire is available on request. To analyze the consumers’ responses, one point was assigned to each item when the answer was right and no point was assigned for “not sure” or a wrong answer.

Consumer test

One hundred consumers participated in the study. All of them participated under all three evaluation conditions: expected, blind and informed. The study was divided into two parts. In the first part the six biscuit samples were presented without any information (blind conditions) and consumers were asked to evaluate their liking, purchase intention and perception of healthiness. Liking was evaluated by using a nine-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”), purchase intention was evaluated with a five-point scale ranging from 1 (“I would definitely not buy it”) to 5 (“I would definitely buy it”) and a 7-point scale ranging from 1 (“not very healthy”) to 7 (“very healthy") was used for the consumers' estimate of how healthy they found each sample.

In the second part, three weeks later, the participants first evaluated only the image of the label (expected conditions). Each label contained different information, according to the composition of the sample (Table 1). Figure 1 shows the label for the olive oil biscuits at 10.6% fat content as an example of how the fat source and the nutritional claim ("Low in saturated fat") were presented on the label.

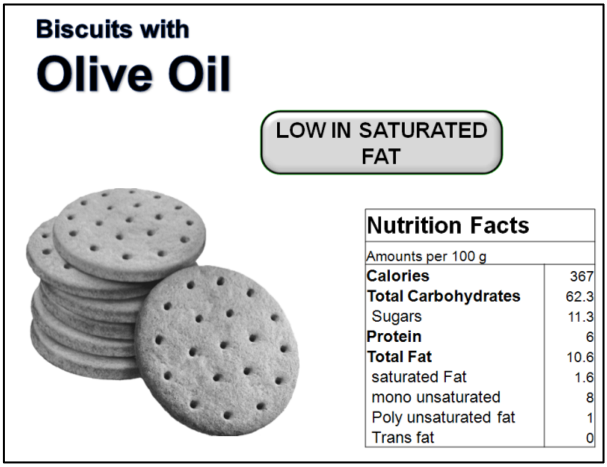

Figure 1. Example of a label created for this study.

The consumers were asked to look at the label and to indicate how much they would like the biscuit, their purchase intention, and how healthy they considered the biscuit, using the same scales as before.

Subsequently, they were given both the images of the labels and the corresponding biscuit samples (informed condition) and were again asked to taste the biscuits and rate their liking for them, their purchase intention and the degree of healthiness of the biscuits in the same way.

The evaluations were carried out in a standardized test room (ISO 2007) and the sample biscuits were served in white plastic dishes. The labels and samples were identified with random three-digit codes and were presented monadically following a balanced design (McFie et al., 1989).

Data analysis

Analysis of variance (ANOVA) of two factors (nutritional knowledge level and sample) and their interactions was performed on the liking and perceived healthiness data obtained under expected, blind and informed conditions. The significance of the differences between samples was determined by Fisher's test ($\alpha=0.05$).

The effects of fat source and fat content on the liking and healthiness data were studied by two-way ANOVA with interactions. The significance of the differences between samples was determined by Fisher's test ($\alpha=0.05$). The individual likings and perceptions of the healthiness of the samples were analyzed by Principal Component Analysis (PCA). From the purchase intention data, the percentage of consumers that definitely/probably would buy each sample and the percentage of consumers that definitely/probably would not buy the product were calculated. All these analysis were performed separately for the data obtained under expected, blind and informed conditions.

Finally, Student's t tests ($p\leq0.05$) were carried out to detect the differences between the expected and blind (E-B), informed and blind (I-B) and informed and expected (I-E) conditions. All the analyses were carried out with XLSTAT 2009.4.03 (Addinsoft, Barcelona, Spain).

RESULTS AND DISCUSSION

Consumers' knowledge about fat. Effect on liking and perceived healthiness of biscuits

Answers to the 27-item questionnaire (Table 2) were analyzed for each consumer to evaluate his/her knowledge about fat in foods. The consumers' scores varied from 6 to 26 with an average of 19.2, which means that on average they answered 71% of the items correctly (Table 2).

Table 2. Average scores of the knowledge questionnaire on fat issues

Questionnaire section	All consumers (n=100)		Low knowledge group (n=30)		High knowledge group (n=70)	
	Average	Sum	Average	Sum	Average	Sum
1: Fat content in foods (7items)	0.77	5.38	0.71	5.00	0.79	5.54
2: Saturated fat content in foods (10 items)	0.73	7.29	0.56	5.55	0.80	8.01
3. Fatty acids and fat sources (10 items)	0.66	6.55	0.35	3.20	0.77	7.72
Total	0.71	19.23	0.52	13.75	0.79	21.28

The level of knowledge did not change much over the three sections but the percentage of correct answers decreased slightly as the questions in the section became more specific: 77% for section 1 (fat content in food products), 73% for section 2 (saturated fat content in food products) and 66% for section 3 (fatty acid types and fat sources).

According to each consumer's total score, he/she was assigned to a level of knowledge (low or high). The low knowledge group (score <18) comprised 30 consumers that on average only answered 50% of the items correctly. The high knowledge group comprised 70 consumers (score >18) that on average answered 79 % of the items correctly.

For each knowledge level, Table 2 also shows the average partial scores obtained in each section. For the high-knowledge group the number of correct answers was high in all the sections (77-80%), indicating that these consumers were aware not only about the fat content of foods but also about differences among fatty acids and fat sources. In the low-knowledge group, the scores for each section were very different among sections. For section 1, the number of correct answers was relatively high (71%), close to the average score of the high- knowledge group. The percentage of correct answers was lower in section 2 (56%) and much lower in section 3 (35%). These results indicated that the consumers in the low-knowledge group were familiar with the amount of fat in foods but not with the amount of saturated fat and had serious difficulties in differentiating types of fatty acids and fat sources.

To discover whether the two different groups of consumers perceived the biscuit label information and the products differently, ANOVA of two factors (sample and knowledge level) with interactions was applied to the liking and healthiness values obtained under the three conditions studied (expected, blind and informed). As can be seen in Table 3, the liking scores varied significantly by sample under all three conditions but the effect of the knowledge level was not significant, indicating that liking for the biscuits did not vary among the consumers according to their level of knowledge about fat

Table 3. Two-way analysis of variance of the effect of sample and knowledge group (KG) with interaction for liking and healthiness perception under expected, blind and informed conditions.

Factor	LIKING						HEALTHINESS PERCEPTION					
	Expected		Blind		Informed		Expected		Blind		Informed	
	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value
Sample	10.4	< 0.001	9.2	< 0.001	3.2	0.007	32.1	< 0.001	1.8	0.119	31.6	< 0.0001
KG	0.2	0.657	4.3	0.039	2.1	0.153	10.5	0.001	6.9	0.009	9.1	0.003
Sample*KG	0.9	0.476	1.1	0.372	0.1	0.982	3.1	0.009	0.9	0.508	3.3	0.006

This result coincides with previous studies where the influence of nutrition knowledge on food preferences has been small (Shepherd, 1992; Wardle et al., 2000) and other consumer factors like familiarity, an interest in health, or preconceptions about the product may have been more responsible for the differences in liking for the food.
However, the healthiness perceived by consumers under the expected and informed conditions varied depending on both the sample and the level of knowledge, with a significant interaction effect among the two factors. The average of perceived healthiness values of each knowledge level group under expected conditions are charted in Fig. 2. The same trend was observed for perceived healthiness under informed condition.

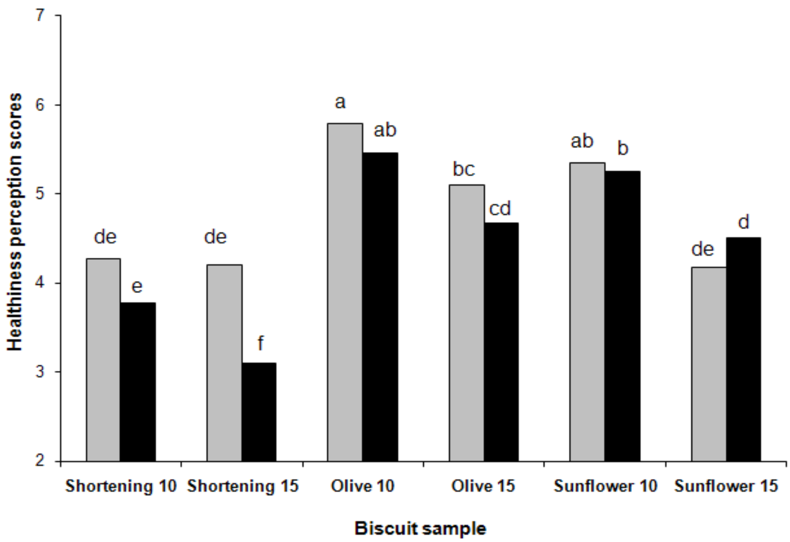

Figure 2. Healthiness perception of biscuit evaluated under the expected condition. Grey: Low-knowledge group; black: High-knowledge group. Scores not sharing letters were significantly different (p≤ 0.05) according to Fisher test.

The high-knowledge consumers perceived the shortening biscuits as less healthy than the vegetable oil biscuits and the high-fat biscuits as less healthy than the low-fat ones. The low-knowledge group also found the shortening biscuits less healthy than the vegetable oil biscuits, though the difference between them was lower because these consumers did not perceive shortening biscuits as being as bad for the health as the high-knowledge consumers did. Furthermore, the reduced fat content only increased the perception of healthiness among the low-knowledge consumers in the case of vegetable oil biscuits that presented the claim “low in saturated fat” and not in that of shortening biscuits where the low fat level was only indicated in the nutritional facts table. It seems that the low-knowledge consumers paid attention to the nutritional claims “with olive oil” and “low in saturated fat” but did not use the information in the nutritional facts table to evaluate healthiness.

Regarding the healthiness perceived under blind condition, the values varied slightly depending on the consumers' level of knowledge (4.6 and 4.3 for the low- and high-knowledge groups respectively) and did not vary significantly among the samples.

Effect of fat source and fat content on consumers liking and healthiness perception of biscuits under expected, blind and informed conditions

Expected condition

According to the ANOVA results, the expected liking values varied significantly with both fat source and fat content (Table 4)

Table 4. Two-way analysis of variance of the effect of fat type and fat content with interaction for liking and healthiness perception under expected, blind and informed conditions.

Factor	LIKING						HEALTHINESS PERCEPTION			
	Expected		Blind		Informed		Expected		Informed	
	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value	F-ratio	p-value
Fat type	37.5	< 0.001	2.5	0.087	3.9	0.021	123.7	< 0.001	131.7	< 0.001
Fat content	22.7	< 0.001	72.0	< 0.001	16.4	< 0.001	75.0	< 0.001	35.9	< 0.001
Fat type*fat content	0.3	0.763	6.2	0.002	2.9	0.053	1.9	0.150	<0.1	0.983

In general, the expected liking values were higher for low fat biscuits than for high fat ones and higher for biscuits with vegetable oils than for those with shortening. Thus, the biscuit labels that stated "with sunflower oil", "with olive oil" and "low in saturated fat" (Sunflower 10 and Olive 10) were those that elicited the best hedonic expectations from the consumers (6.3-6.7), while the sample with a high fat content of shortening (Shortening 15) presented the lowest expected liking (5.2) (Table 5).

Table 5. Mean liking scores and mean healthiness perception values of biscuits evaluated under expected, blind and informed conditions.

Sample	Liking			Healthiness perception	
	Expected	Blind	Informed	Expected	Informed
Shortening 10	5.6^{de}	5.7^{b}	5.7^{c}	3.9^{c}	3.8^{d}
Shortening 15	5.2^{e}	6.1^{ab}	5.8^{bc}	3.4^{d}	3.2^{e}
Olive 10	6.7^{a}	5.2^{c}	5.9^{bc}	5.6^{a}	5.5^{a}
Olive 15	6.2^{bc}	6.3^{a}	6.5^{a}	4.8^{b}	4.9^{bc}
Sunflower 10	6.4^{ab}	5.1^{c}	5.7^{c}	5.3^{a}	5.1^{ab}
Sunflower 15	5.8^{cd}	6.2^{ab}	6.3^{ab}	4.4^{b}	4.6^{c}

Means in the same column with different letters are significantly different ($p \leq 0.05$) according to Fisher's least significant difference.

Thus, a large proportion of the consumers declared that they would probably or definitely buy biscuits with a low fat content of olive or sunflower oil (64% and 56% respectively) while only 18% of the consumers would buy biscuits with a high fat content of shortening (Table 6)

Table 6. Consumers' biscuit purchase intentions under expected, blind and informed conditions

Sample	Consumers that probably/definitely would buy it (%)			Consumers that probably/definitely would NOT buy it (%)		
	Expected	Blind	Informed	Expected	Blind	Informed
Shortening 10	31	25	29	29	42	35
Shortening 15	18	37	24	34	29	41
Olive 10	64	14	39	7	56	29
Olive 15	44	40	55	16	26	18
Sunflower 10	56	17	37	17	61	35
Sunflower 15	28	37	44	26	25	17

The consumer preference map under expected condition (Fig. 3) explained 66.6% of the variability in liking

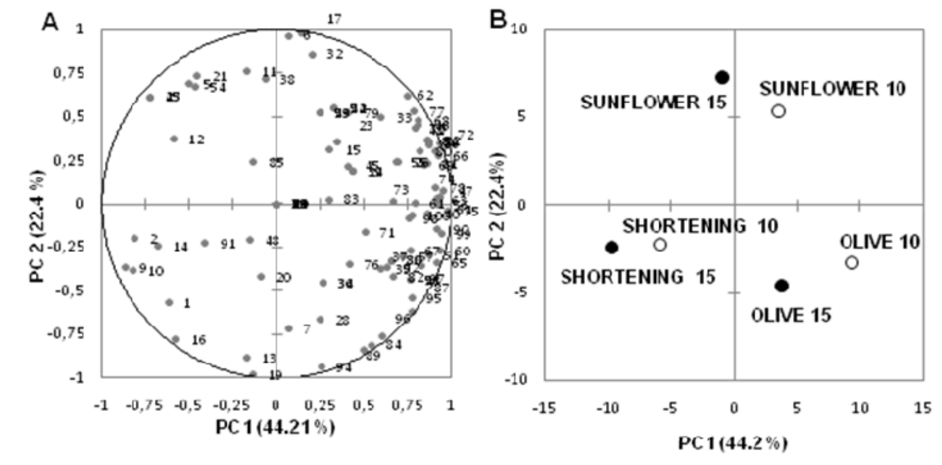

Figure 3. Consumers' preference map of biscuits evaluated under the expected condition: (A) consumers' representation and (B) samples' representation

A large number of the consumers thought that they would not like the biscuits made with shortening very much, although part of them would prefer the biscuits made with sunflower oil (upper side) and the other part would prefer the biscuits with olive oil (lower half) (Fig. 3A). The consumers situated in the upper left quadrant of the plot would not like the biscuits made with olive oil. Finally, the group of consumers in the lower left quadrant thought that they would like the biscuits with shortening but not the ones with sunflower oil.

The perception of healthiness that the consumers received from the biscuit label information also varied depending on the fat source and content (Table 4). When the presence of olive or sunflower oil was indicated on the label, the consumers thought that the biscuits were healthier than when no information about the fat source was indicated. A reduced fat content also increased the consumers' perception of healthiness. The biscuits considered the healthiest were those for which the label presented the fat source claim "with olive oil" or "with sunflower oil" or "low in saturated fat" and the nutritional facts presented lower calorie and fat content values. The Shortening 15 biscuit label, which did not give any indication of fat source and presented higher amounts of calories, fat and saturated fats in the nutritional table, made the consumers perceive the biscuits as less healthy (Table 5). The PCA of the consumers' perception of healthiness under expected condition accounted for 71.4% of the variability (Fig. 4). The samples were classified into three groups according to the fat source. On looking at the consumers plot (Fig. 4A) it can be seen that they are mainly situated on the right side, indicating agreement that the samples with shortening were perceived as the least healthy. One group perceived the olive oil samples as healthier than the sunflower oil ones (lower right quadrant) and another group (upper right quadrant) perceived the sunflower oil biscuits as healthier. These results show that when the consumers read the information on the label they had a correct idea of the beneficial effect of the vegetable oils and the negative effect of saturated fats. The consumers also took the amount of fat or the calorie content into account in evaluating the samples' healthiness.

However, they attached much more importance to fat type (saturated fat versus vegetable oils) than to fat content

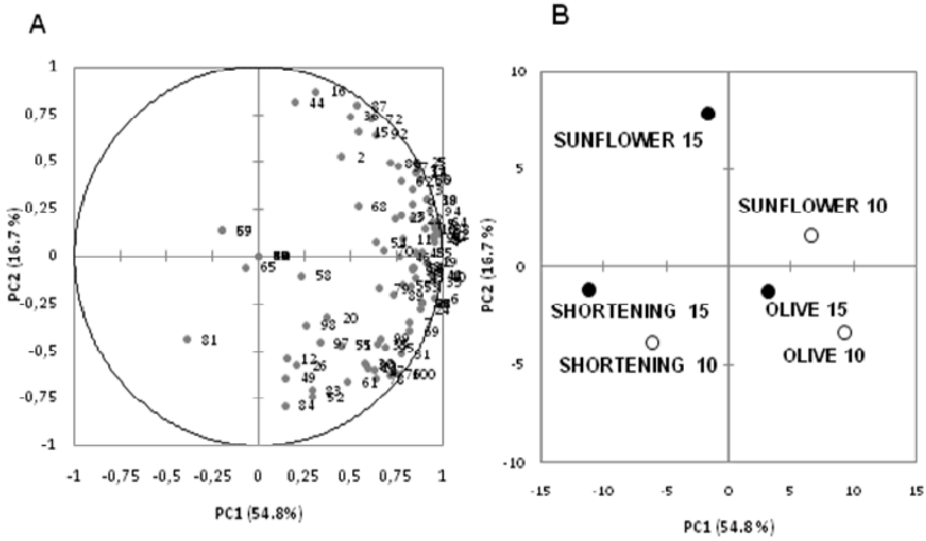

Figure 4. PCA of consumers' healthiness perception of biscuits under the expected condition: (A) consumers' representation and (B) samples' representation.

A similar effect was observed by Räsänen et al, 2003 in a longitudinal study about the impact of nutritional counselling on food intake, which found that the counselled group ate less saturated fat but had the same total fat intake as the control. This information seems to indicate that when information on the fat source is provided, consumers may attach less importance to the total fat level. Although more evidence of this effect is needed, it should be taken into account in campaigns to improve nutritional knowledge and in advertising.

Blind condition

When the consumers tasted the biscuits under the blind condition a significant interaction was found between the effects of the two factors on their liking for the biscuits (Table 4). The highest liking values (6.1 to 6.3) were found in the high fat content samples, with no significant differences among the three types of fat (Table 5), and about 37%-40% of the consumers would definitely or probably buy these biscuits. The lower fat content significantly decreased the liking for the biscuits with vegetable oils, but not for the shortening biscuit. Thus, low fat content vegetable oil biscuits were the least preferred, with only 14%-17% of consumers willing to buy them (Table 6).

The preference map under blind conditions explained 60% of the variability among the consumers (Fig. 5)

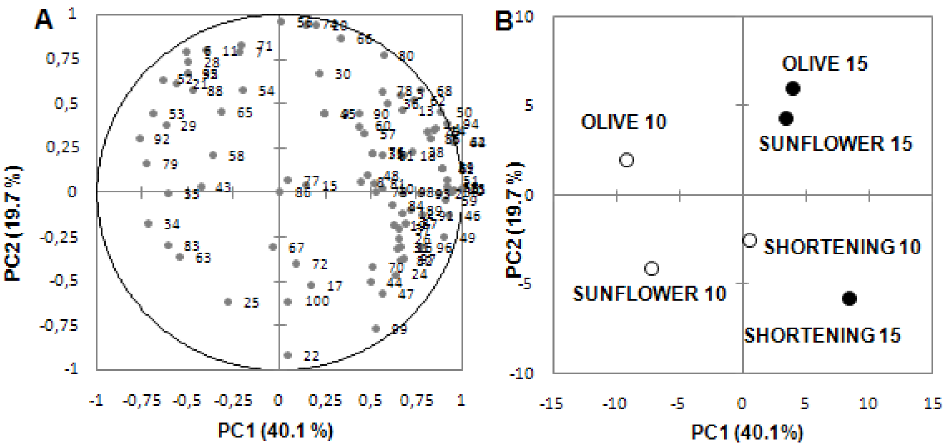

Figure 5. Consumers preference map of biscuits evaluated under the blind condition: (A) consumers' representation and (B) samples representation.

On looking at their distribution (Fig. 5A), most of the consumers preferred the high fat biscuits (upper and lower right side of the plot). There was also another small group (situated in the upper left quadrant) that did not like the shortening biscuits but did like the Olive 10 biscuits.

As mentioned above (section 3.1), under the blind conditions there was no variation in perceived healthiness among the samples (scores from 4.2 to 4.6), indicating that when the consumers tasted the biscuits without any information, they had the same perception of healthiness for all the biscuits.

Informed condition

When the consumers tasted the samples and also had the label information, the liking scores varied to a lesser extent than under the expected and blind conditions. Both fat type and content had a significant effect (Table 4). The Olive 15 and Sunflower 15 biscuits presented higher liking scores (6.5 and 6.3, respectively) than their low fat counterparts and than the shortening biscuits, which did not differ significantly among each other (from 5.7 to 5.9) (Table 5). The two first dimensions of the preference map (Fig. 6) explained only 52% of the variability and the consumers were more dispersed over the map, indicating that the consumers' behaviour was less uniform under informed condition

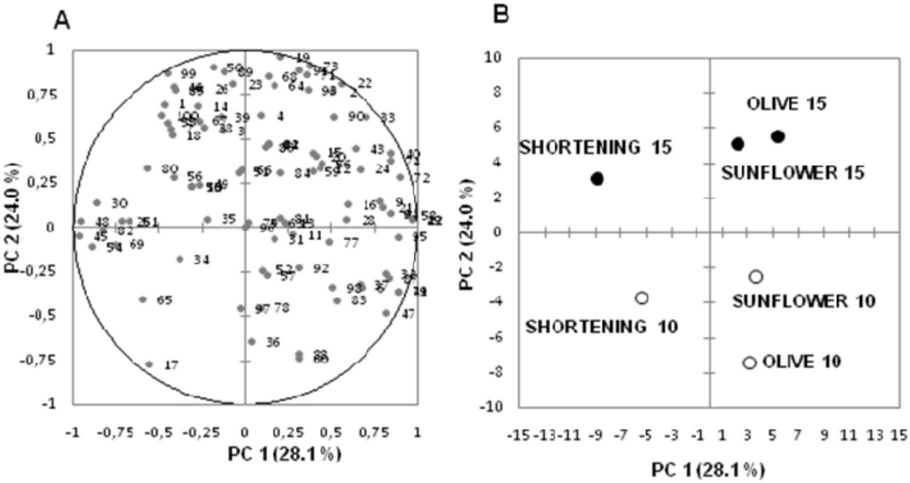

Figure 6. Consumers' preference map of biscuits under the informed condition: (A) consumers representation and (B) samples representation.

The largest group, situated in the upper right quadrant of the plot, preferred the vegetable oil biscuits with the higher fat content (Fig. 6a). The group situated in the bottom right quadrant preferred the vegetable oil biscuits with the lower fat content. Finally, a third group liked the Shortening 15 biscuits the most and did not like the Sunflower 10 and Olive 10 biscuits.

The consumers' perception of healthiness when tasting the biscuit and looking at its label varied significantly with both fat source and fat content (Table 4). In general, the consumers perceived the high fat biscuits as being less healthy than the low fat biscuits and the shortening biscuits as less healthy than those with vegetable oils. Thus, similarly to expected condition, the least healthy biscuit was considered to be Shortening 15 (no fat source claim in the label and high calorie, fat and saturated fat contents in the nutritional facts table), with an overall liking score of 3.2 (Table 5). On the other hand, the biscuits with the fat source claims "with olive oil" or "with sunflower oil" and with the nutritional claim "low saturated fat content" were perceived as significantly healthier than the rest (scoring 5.5 and 5.1 respectively) (Table 5). The PCA plot of the perceived healthiness of the samples under informed condition accounted for 74.3% of the variability (Fig. 7). In general, the consumers agreed in considering the vegetable oil biscuits healthier than those with shortening. Some (upper half) considered the olive oil biscuits the healthiest and others (lower half) considered the sunflower biscuits the healthiest.

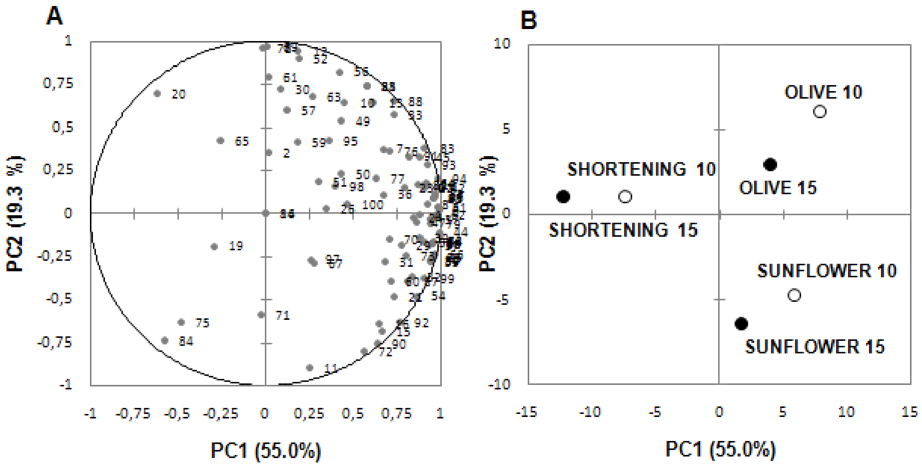

Figure 7. PCA of consumers' healthiness perception of biscuits under the informed condition: (A) consumers' representation and (B) samples' representation.

Comparison between expected, blind and informed condition

Liking

In order to study how liking is influenced by the expectations generated by the label information, the average scores for each sample in blind (B), expected (E) and informed conditions (I) were compared. For each sample, expected minus blind scores (E-B), informed minus blind scores (I-B) and informed minus expected scores (I-E) were calculated and a paired *t* test was carried out to evaluate significant differences between the mean ratings for the conditions studied (Table 7).

Table 7. Mean values (M) and significance (p, probability according to t-test) of differences between liking values for biscuit samples under different conditions

Sample	E - B		I - B		I - E	
	M	p	M	p	M	p
Shortening 10	-0.2	0.35	<0.1	0.95		
	N.S		N.S			
Shortening 15	-0.9	0.00	-0.3	0.17		
	Disconfirmation (+)		N.S.			
Olive 10	1.5	< 0.0001	0.7	0.00	-0.8	< 0.0001
	Disconfirmation (-)		Assimilation		Incomplete assimilation	
Olive 15	-0.1	0.51	0.2	0.23		
	N.S.		N.S.			
Sunflower 10	1.3	< 0.0001	0.6	0.001	-0.7	< 0.0001
	Disconfirmation (-)		Assimilation		Incomplete assimilation	
Sunflower 15	-0.4	0.04	0.1	0.62		
	Disconfirmation (+)		N.S.			

B, blind; E, expected; I, informed; N.S., not significant.

As shown in Table 7, the Shortening 10 and Olive 15 biscuits did not display significant differences between the expected and blind conditions (E-B), indicating that the expectations created by the label were met. In the case of the Olive 15 biscuit, the label presented the fat source claim “with olive oil” and the calorie and fat content levels were high but were mostly mono unsaturated fat. This label created high hedonic expectations in the consumers that were fulfilled when they tasted the biscuit. In the case of Shortening 10, the label did not present any fat source claim and the calorie and fat content levels were low but most of the fat was saturated. This label caused low expectations in the consumers that were confirmed when they tasted the biscuit.

The rest of the samples showed significant differences between the liking scores under expected and blind conditions (E-B), indicating disconfirmation. In the Shortening 15 and Sunflower 15 samples, the difference was negative (positive disconfirmation), meaning that when the consumers tasted the samples they liked them more than they had expected. It seems that the consumers expected the high fat content biscuits to be less desirable/likable compared to the rest but when they tasted them they liked their sensory characteristics (these were the samples with the highest scores under blind conditions) (Table 5). Furthermore, in both cases the differences between the results under informed and the blind conditions (I-B) were not significant, indicating that the informed liking scores coincided with the blind scores. The information on the label (lack of fat source claim and high level of fat and saturated fat; or "with sunflower oil" and high level of fat and polyunsaturated fat) had a negative effect on the consumers' expectations but this information did not affect the actual liking for the product under informed conditions, where the consumers paid more attention to the sensory properties of the biscuits.

In the case of the Olive 10 and Sunflower 10 biscuits, the differences between the expected and blind conditions were positive (E>B), the disconfirmation was negative, implying that consumers found these samples worse than they had expected. This negative disconfirmation seems to indicate that the consumers were not aware of the negative changes in sensory properties caused by fat reduction in biscuits. This could be because most of the consumers had probably not tried a low-fat biscuit previously, or because they were not aware that 10.6% fat in a biscuit is a severe fat reduction. Consumer perceptions about fat reduction depend to a high degree on the product. Expectations are usually low for reduced-fat versions of products such as chocolate and ice cream, as consumers know the importance of fat in the pleasure that these products provide (Tuorila, 1992). In the present study, the results showed that consumers did not associate a low-fat biscuit with poor sensory properties, which is a good point for the development of such a type of biscuit. In both cases, the differences between the informed and blind conditions (I-B) were significant and the (I-B)/(E-B) result was positive, indicating an assimilation effect.

The positive effect of label information on expected liking was also observed in informed liking. Thus, the information included on the label (the fat source claim “with olive oil” or “with sunflower oil” and the nutritional claim “low saturated fat content”) made consumers increase their liking scores despite the fact that these samples obtained the lowest liking scores when evaluated under blind condition, when the samples were only rated according to their intrinsic sensory properties. In order to see whether or not the assimilation of the information was complete, the differences in the mean informed minus expected scores (I-E) were calculated. Since the difference was significant for both samples (Sunflower 10 and Olive 10 biscuits), the assimilation was incomplete, revealing that the sensory quality of the samples and the information provided both affected the actual liking for the samples (informed condition). If consumers do not completely assimilate towards expectations, it can be assumed that they will revise their expectation in subsequent exposures, as observed by Lange, Rousseau, and Issanchou, (1998). In these cases it is advisable to improve the product's sensory properties in order to avoid the consumers' finally harbouring negative expectations about the product.

Healthiness

Following the study of the effect of the information on liking for the biscuits, using expectation theory, the consumers' concept of healthiness was also explored. In this case, the E-B difference would indicate how much the perception of healthiness perception evaluated according to label differed from that perceived in blind condition (without label). In the Sunflower 15 and Olive 15 biscuits these differences were not significant (Table 8), indicating that the healthiness the consumers perceived from the label information about the fat source ("with olive oil"; "with sunflower oil") matched their concept of the healthiness of these biscuits when no information was provided

Table 8. Mean values (M) and significance (p, probability according to t-test) of differences between perceived healthiness values fot biscuits samples under different conditions.

Sample	E-B		I-B		I-E	
	M	p	M	p	M	p
Shortening 10	-0.5	0.00	-0.6	0.00	-0.1	0.38
	Disconfirmation (+)		Assimilation		Complete assimilation	
Shortening 15	-0.9	< 0.0001	-1.1	< 0.0001	-0.2	0.24
	Disconfirmation (+)		Assimilation		Complete assimilation	
Olive 10	1.3	< 0.0001	1.3	< 0.0001	-0.1	0.37
	Disconfirmation (-)		Assimilation		Complete assimilation	
Olive 15	0.2	0.16	0.3	0.02		
	N.S.		N.S.			
Sunflower 10	1.0	< 0.0001	0.8	< 0.0001	-0.2	0.14
	Disconfirmation (-)		Assimilation		Complete assimilation	
Sunflower 15	-0.2	0.28	0.0	0.98		
	N.S.		N.S.			

B, blind; E, expected; I, informed; N.S., not significant.

For the Shortening 10 and Shortening 15 samples, the differences between the expected and blind conditions were both significant and these differences were negative (E<B), indicating that according to the label information (no fat source or nutritional claim, nutritional facts table), the consumers thought that these

biscuits were less healthy than the idea of healthiness they generally had for a biscuit. For the Olive 10 and Sunflower 10 biscuits, the mean healthiness values under the expected conditions were significantly higher than in the blind conditions, so the differences (E-B) were significant and positive. That is to say, the label information (“with olive oil”, “with sunflower oil” and “low saturated fat content”) made the consumers think that these biscuits were healthier than they had thought when no information was provided. For these four samples, the differences between the informed and blind condition (I-B) were significant and the differences between informed and expected condition (I-E) were no significant indicating a complete assimilation and that there was no difference in perceived healthiness when evaluating only the label and when evaluating both the label and the biscuit. Consequently, in these cases the evaluation of the samples’ healthiness was only based on the label information and was unaffected by the hedonic characteristics of the samples.

CONCLUSIONS

The information on the labels of the biscuits made with olive oil or sunflower oil increased the perception of healthiness and caused higher hedonic expectations among the consumers than that on the labels of biscuits made with dairy shortening. The consumers considered low fat biscuits with a vegetable oil to be the healthiest and expected they would like them the most. However, their actual liking for the biscuits was influenced by both the sensory and the label information and the most-liked biscuits were those with a vegetable oil at a high fat content.

The consumers’ level of knowledge about fat did not affect their liking for biscuits made with different fat sources and contents but did affect their perception of healthiness. High-knowledge consumers considered shortening biscuits much less healthy than low-knowledge consumers and also paid more attention to the nutritional facts table.

Liking for the biscuits was influenced by the label information but the perceived healthiness of the biscuits was based on the label information alone and was unaffected by the hedonic characteristics of the samples.

ACKNOWLEDGEMENTS

The authors wish to thank the Spanish Ministry of Science and Innovation (AGL 2009-12785- C02-01 for financial support and for Tarrega's contract within the Juan de la Cierva Programme and The Dow Chemical Co. (Michigan, USA) for providing free samples of the ingredients.

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RESUMEN DE RESULTADOS

Efecto del reemplazo de mantequilla por aceite de girasol. Efecto en la textura y propiedades reológicas de la masa y en la textura y aceptabilidad de las galletas horneadas

En esta tesis se ha estudiado cómo afecta la sustitución de la grasa convencional (rica en ácidos grasos saturados) por aceites vegetales a las propiedades de la masa de galleta así como a la textura instrumental, a las propiedades sensoriales y a la aceptabilidad de la galleta horneada. Para poder utilizar el aceite en forma sólida, en esta tesis se propone y evalúa el uso de un sistema aceite/gel en el que el aceite queda atrapado en una matriz de gel de hidrocoloide.

La primera parte de la tesis consistió en un primer estudio exploratorio para evaluar los efectos causados por la sustitución de mantequilla por un sistema aceite de girasol/gel que además suponía una reducción drástica en el contenido de grasa de la galleta (41% menos de grasa). Se utilizaron sistemas elaborados con aceite de girasol y tres tipos de éteres de celulosa con distinto grado de metoxil e hidroxipropil sustitución y se evaluó si el grado de metoxil e hidroxipropil sustitución de estos éteres de celulosa afectó a la textura de la masa y de la galleta, así como a la aceptabilidad general y a la aceptabilidad de la apariencia, color, textura, sabor y dulzor de la galleta. Los resultados del estudio de la textura de la masa (ensayo de corte y ensayo de doble compresión) indicaron que las masas con los sistemas de aceite de girasol/gel presentaron menores valores de fuerza en el ensayo de corte que las galletas elaboradas con mantequilla. Por lo tanto, las masas con los distintos sistemas de aceite de girasol/gel resultaron menos duras. En las galletas horneadas, tanto los valores del diámetro como los del espesor de las galletas elaboradas con los sistemas aceite de girasol/gel fueron mayores que en las galletas con mantequilla. Esto indicó que las galletas elaboradas con los sistemas aceite de girasol/gel se expandieron en mayor grado que las galletas con mantequilla, lo cual sugiere que el aumento de la elasticidad de la masa no afectó a la expansión de las galletas tras el horneado. En cuanto a las propiedades mecánicas de las galletas, los resultados del ensayo de flexión y de penetración con diente indicaron que, en general, no hubo apenas diferencias entre los valores de fuerza máxima de rotura y los de fuerza máxima de penetración entre los distintos sistemas de aceite de girasol/gel con respecto a las galletas elaboradas con mantequilla. En lo referente al estudio de la aceptabilidad general y de la aceptabilidad de la apariencia, color, textura, sabor y dulzor realizado por consumidores, los resultados indicaron que la aceptabilidad para las galletas con los distintos sistemas aceite de girasol/gel fueron similares entre ellas aunque éstas presentaron diferencias con las galletas elaboradas con mantequilla, principalmente en cuanto a la aceptabilidad global y a la textura y, en menor medida, al sabor.

Para una mejor comprensión de los cambios ocurridos en la estructura de las masas elaboradas con los distintos sistemas aceite de girasol/gel se estudiaron las propiedades reológicas de las masas mediante ensayos de viscoelasticidad lineal oscilatorios y ensayos de fluencia.

Los resultados de los ensayos oscilatorios revelaron que las masas elaboradas con los distintos sistemas aceite de girasol/gel presentaron valores del módulo elástico (G’) y del módulo de almacenamiento (G’’) inferiores a los de la masa elaborada con mantequilla, indicando que las masas elaboradas con los sistemas aceite de girasol/gel presentaron un comportamiento más próximo a una estructura líquida. El grado de metoxil e hidroxipropil sustitución de la celulosa no tuvo un efecto significativo en las propiedades reólogicas de las masas de galleta, al igual que ocurría en las propiedades de textura y sensoriales. Por otro lado, los valores de capacitancia obtenidos durante el ensayo de fluencia se ajustaron satisfactoriamente al modelo de Burger. Se observó que las masas elaboradas con los sistemas aceite de girasol/gel presentaron menor resistencia a la deformación en comparación con las masas elaboradas con mantequilla lo cual indicó la menor elasticidad de las masas elaboradas con los sistemas aceite de girasol/gel y que esta elasticidad estuvo relacionada con la expansión de la masa tras el horneado.

Efecto del tipo y cantidad de grasa en las propiedades sensoriales de las galletas percibidas por los consumidores. Relación con las propiedades mecánicas y acústicas

Puesto que la sustitución directa de la grasa convencional (rica en ácidos grasos saturados) por el sistema de aceite de girasol/gel y una reducción elevada del contenido de grasa en la galleta produjo cambios en su aceptabilidad, en esta segunda parte se propuso el estudio de sistemas aceite/gel alternativos como el uso de aceite de oliva, el uso de otro hidrocoloide como la goma xantana así como una reducción menor del contenido de grasa. Se estudiaron las diferencias en las propiedades sensoriales percibidas por los consumidores durante el consumo de galletas elaboradas con distinto tipo y cantidad de grasa y para entender las propiedades mecánicas y acústicas responsables de dichos cambios percibidos en boca se evaluó la textura instrumental de las galletas.

Para ello, se estudiaron un total de 16 formulaciones distintas de galleta. Se utilizaron dos grasas convencionales con elevado contenido en ácidos grasos saturados (mantequilla y margarina) al 18% de grasa para la elaboración de las galletas control. Con respecto a la cantidad de grasa, se estudiaron dos niveles de reducción de grasa: un nivel de reducción alto (10,6% de grasa) y uno bajo (15,6% de grasa). A estos dos niveles se prepararon galletas con seis tipos distintos de grasa: mantequilla, margarina, un sistema aceite de oliva/hidroxipropilmetilcelulosa, un sistema aceite de girasol/ hidroxipropilmetilcelulosa, un sistema aceite de oliva/goma xantana, un sistema aceite de girasol/goma xantana y, por último, un sistema aceite de girasol/hidroxipropilmetilcelulosa al que se le añadió aroma de mantequilla.

En primer lugar se evaluaron las diferencias en la textura y el sabor de las galletas mediante la técnica de perfil sensorial de libre elección llevado a cabo por 28 consumidores. Se propuso una modificación de la técnica que permitió la evaluación de las distintas sensaciones percibidas a lo largo del consumo de las galletas. En cuanto a la evaluación de la percepción de los distintos atributos a lo largo del proceso de consumo (primer bocado, masticación y formación del bolo e ingestión), los resultados mostraron que la complejidad de las diferencias que los consumidores percibieron entre las distintas muestras fue mayor a medida que avanzaba el proceso de consumo. Así, en la primera etapa, las diferencias entre las muestras se debieron principalmente a las diferencias en la textura de las mismas y todos ellos coincidieron en la utilización de la dureza para describir las diferencias entre muestras al primer bocado. En cambio, en las siguientes etapas las diferencias entre muestras se explicaron por una combinación de las diferencias en la textura y también en el sabor de las galletas. Los resultados de la evaluación sensorial mostraron que una elevada disminución del contenido de grasa (de un 18% de grasa a un 10,6% de grasa) en galletas con grasa convencional (mantequilla o margarina) dio lugar a galletas considerablemente más duras, secas y con menos sabor. En cambio, con una reducción menos drástica (del 18% a 15,6% de grasa), las galletas obtenidas presentaron propiedades sensoriales similares a las de las galletas control (18% de grasa). En cuanto a la sustitución de la mantequilla o margarina por los sistemas aceite de oliva o girasol/gel, los cambios en las propiedades sensoriales producidos dependieron del sistema utilizado. Las galletas elaboradas con sistemas con goma xantana (con aceite de girasol o de oliva) presentaron las características sensoriales que más diferían de las galletas elaboradas con mantequilla o margarina siendo más duras y secas y con menor sabor. En cambio, las galletas elaboradas con los sistemas aceite de oliva y girasol, ambos con hidroxipropilmetilcelulosa, presentaron características sensoriales similares a las de las galletas elaboradas con mantequilla o margarina aunque algunos consumidores percibieron un sabor extraño en las galletas elaboradas con aceite de oliva.

El siguiente paso fue evaluar los cambios en las propiedades mecánicas y acústicas de las galletas y relacionarlos con las propiedades de textura percibidas por los consumidores para entender cuáles son las propiedades físicas que cambian con el tipo y cantidad de grasa en las galletas y son responsables de los cambios percibidos en boca. Se utilizaron distintos tipos de ensayos instrumentales de textura como el ensayo de flexión hasta rotura y dos tipos de ensayo de penetración con distintas geometrías (sonda cilíndrica y sonda esférica). Además, mediante el uso de un micrófono acoplado al texturómetro, se midieron simultáneamente los eventos de sonido emitidos durante dichos ensayos de flexión y penetración Se obtuvieron un total de 38 parámetros instrumentales para caracterizar las diferencias en la respuesta mecánica y acústica de las galletas. Mediante análisis de regresión se estableció la relación entre los parámetros instrumentales y las sensaciones de textura percibidas por cada uno de los consumidores. Los resultados mostraron que las galletas con contenido reducido en grasa presentaron mayores valores de fuerza de resistencia a la rotura y a la penetración y también más fracturas durante la penetración con cilindro lo que explicó que en boca fueran percibidas como más duras y crujientes durante el primer bocado y la masticación. Por otro lado, el efecto de la reducción de grasa fue menos pronunciado en las galletas elaboradas con grasa convencional que en las elaboradas con los sistemas aceite vegetal/gel. En el caso de los sistemas preparados con goma xantana, la sustitución de la mantequilla o margarina por estos sistemas dio lugar a unas galletas más elásticas, más resistentes a la rotura y con mayores eventos de sonido durante la penetración, aumentando la sensación de dureza percibida por los consumidores. Además, en general, al disminuir el contenido de grasa, o al sustituirla por los sistemas aceite vegetal/gel, el número de eventos de fuerza (>0,1 N) durante la penetración con esfera disminuyó y las galletas fueron percibidas como menos arenosas, desmigables o quebradizas. Las galletas que mayor número de eventos de fuerza >0,1 N fueron las galletas elaboradas mantequilla o margarina y fueron percibidas como más arenosas y desmigables que el resto de muestras. Por otro lado, en las galletas con los sistemas aceite vegetal/hidroxipropilmetilcelulosa (aceite de oliva con alto contenido de grasa y aceite de girasol a ambos contenidos de grasa) confirieron propiedades mecánicas y acústicas similares a las presentadas por las galletas con grasa convencional, dando lugar a galletas con propiedades de textura similares en boca.

Aceptabilidad de galletas elaboradas con aceite de oliva y girasol. Efecto de las propiedades sensoriales y la información nutricional

Por último, en esta parte de la tesis se evaluó la aceptabilidad de las galletas y cómo influyeron las características sensoriales y la información nutricional en la aceptabilidad de las mismas. Para ello, se descartaron los sistemas elaborados con goma xantana debido a su gran diferencia en textura con respecto al resto de muestras y se estudiaron las formulaciones de galletas con dos niveles de grasa (15,6 y 10,6%) y elaboradas con el sistema aceite de oliva/hidroxipropilmetilcelulosa y el sistema aceite de girasol/ hidroxipropilmetilcelulosa frente a las formulaciones con mantequilla que, en este caso, fueron las muestras control.

En primer lugar se evaluó la aceptabilidad de las seis formulaciones de galletas por 97 consumidores y las diferencias sensoriales mediante el uso de la técnica de CATA (marque todo lo que corresponda) y se estableció la relación entre ambas para determinar las características sensoriales responsables de las diferencias en la aceptabilidad de las galletas.

Los resultados de las puntuaciones de aceptabilidad para las distintas muestras mostraron una clara dispersión a lo largo y ancho del mapa de preferencia lo cual indicó una cierta heterogeneidad en la respuesta de los consumidores. Para estudiar las causas de esta heterogeniedad se realizó un análisis de conglomerados. Este análisis dio lugar a tres grupos de consumidores con diferentes patrones de preferencia. La relación entre la aceptabilidad y los datos de evaluación CATA se estableció para cada grupo de consumidores mediante análisis multifactorial. Para los consumidores del primer grupo (n=23) las galletas que más les gustaron fueron las elaboradas con aceite de oliva y con mantequilla a nivel alto de grasa (15,6%), las cuales fueron percibidas como fáciles de masticar, fáciles de tragar, crujientes y con sabor intenso a galleta. Por otro lado, a este grupo no le gustaron las galletas con aceite de oliva y de girasol con bajos contenido de grasa y que consideraron difíciles de masticar, duras, con poco sabor y poco dulces. Con respecto al segundo grupo de consumidores (n=47), éstos prefirieron las galletas con mantequilla las cuales percibieron como crujientes, fáciles de masticar y con sabor intenso a galleta. Por otro lado, no les gustaron las galletas con aceite de oliva ni las de aceite de girasol con bajo contenido en grasa que encontraron duras y difíciles de masticar. Para los consumidores del tercer grupo (n=27), la aceptabilidad estuvo relacionada con el sabor a mantequilla, al sabor a tostado y el sabor intenso a galleta los cuales fueron percibidos en las galletas con aceite de oliva y girasol con contenido alto en grasa (15,6%). Aunque estos consumidores percibieron las galletas con mantequilla con 15,6% de grasa como crujientes y fáciles de masticar fueron las muestras que menos les gustaron porque las percibieron con un sabor desagradable. Por tanto, mientras que para los dos primeros grupos, tanto las características de textura como el sabor influyeron en la aceptabilidad, para los consumidores del tercer grupo, fue el sabor lo que más influyó en la aceptabilidad de las galletas.

Finalmente, se estudió cómo variaron las expectativas y la percepción de saludable de los consumidores de acuerdo a la información nutricional de la etiqueta de las galletas y su efecto en la aceptabilidad de las mismas. Se utilizaron las seis formulaciones de galletas del estudio anterior y se diseñaron etiquetas con la correspondiente información nutricional: la declaración de la elaboración con aceite de oliva o de girasol, la declaración de bajo contenido en grasa saturada, y variaciones en cuanto al contenido calórico y contenido en grasa en la tabla de información nutricional. Además, para evaluar si el grado de conocimiento que los consumidores tenían acerca de la grasa en la dieta podía afectar a la aceptabilidad y a la percepción de saludable de las galletas, los participantes del estudio contestaron un cuestionario cuyas preguntas estaban relacionadas con el contenido de grasa en los alimentos, la grasa saturada en los alimentos y los ácidos grasos y sus fuentes en los alimentos.

Para llevar a cabo el estudio de expectativas los consumidores (n=100) evaluaron las galletas y/o las etiquetas correspondientes a cada una de las seis formulaciones en distintos escenarios. En primer lugar, indicaron la aceptabilidad esperada, así como la percepción de saludable de cada una de las muestras, únicamente utilizando la información nutricional correspondiente a cada galleta presentada en las etiquetas (condición esperada). En otra sesión, probaron las muestras sin ningún tipo de información e indicaron su aceptabilidad y la percepción de saludable (condición ciego) y, en la última sesión, indicaron la aceptabilidad de las galletas probándolas y disponiendo de la información nutricional presentada en la etiqueta correspondiente a cada una de las muestras (condición informada).

Los resultados mostraron que las galletas con aceite de oliva y bajo contenido de grasas saturadas fueron aquellas con mayor puntuación en la aceptabilidad esperada en comparación con las galletas grasa convencional rica en ácidos grasos saturados. Esto indicó que, a diferencia de lo ocurrido en otros productos bajos en grasa, no se asoció una galleta con contenido reducido en grasa con una galleta con baja calidad sensorial. En las galletas con contenido alto de grasa (15,6%), la aceptabilidad evaluada en ciego fue similar para las galletas con aceite de oliva, aceite de girasol y mantequilla. No obstante, al probar estas mismas muestras y disponiendo de la información nutricional correspondiente a cada una de ellas, los consumidores aumentaron los valores de aceptabilidad para las galletas con aceite de oliva y girasol mientras que los bajaron en las galletas con grasa convencional rica en ácidos grasos saturados.

En cuanto a la percepción de saludable, los resultados mostraron que los consumidores percibieron las galletas en cuyas etiquetas figuraba la información nutricional “con aceite de oliva “, “con aceite de girasol” y con “bajo contenido de ácidos grasos saturados” como más saludables que las galletas que no presentaban información acerca del tipo de grasa y que tenían un mayor contenido en ácidos grasos saturados.

Sin embargo, las características sensoriales de las galletas no influyeron en la percepción de saludable de los consumidores que únicamente tuvieron en cuenta la información proporcionada por la etiqueta para evaluar cuán saludables consideraban las galletas.

El nivel de conocimiento de los consumidores sobre la grasa en la dieta se evaluó mediante un cuestionario y, de acuerdo a las respuestas los consumidores, éstos se clasificaron en dos niveles. El grupo de consumidores, con un alto nivel de conocimiento nutricional de las grasas, estaba familiarizado con el contenido de grasa en los alimentos, la cantidad de grasa saturada en alimentos y además, los consumidores de este grupo fueron capaces de diferenciar los distintos tipos de ácidos grasos así como las fuentes de grasa de los mismos. En cambio, los consumidores del otro grupo, estaban familiarizados con el contenido de grasa de los alimentos, pero no con la cantidad de grasa saturada en los alimentos, y además, este grupo presentó serias dificultades para diferenciar los distintos tipos de ácidos grasos presentes en las grasas y en qué alimentos se encontraban éstos. Por otro lado se observó que la aceptabilidad de las distintas muestras fue similar para los dos grupos de conocimiento, por lo que el grado de conocimiento sobre la grasa en la dieta no afectó a la aceptabilidad de las galletas por parte de los consumidores. No obstante, la percepción de saludable de las distintas muestras varió en función del grupo de conocimiento al que pertenecían los consumidores. Así, los consumidores con un bajo grado de conocimiento nutricional de las grasas no evaluaron las galletas con elevados contenidos en ácidos grasos saturados tan poco saludables como lo hicieron los consumidores con alto grado de conocimiento sobre las grasas en la dieta.

CONCLUSIONES

1. La sustitución de la grasa utilizada habitualmente en la elaboración de galletas por los sistemas de aceite atrapados en un gel de éteres de celulosa es un proceso viable a escala de laboratorio. Esta sustitución supone una mejora sustancial en la composición de ácidos grasos de las galletas aportando a las mismas una mayor cantidad de ácidos grasos monoinsaturados y poliinsaturados en detrimento de los ácidos grasos saturados y asegura al consumidor la ausencia de ácidos grasos trans.

2. Las medidas reológicas de viscoelasticidad lineal mediante ensayos oscilatorios y de fluencia mostraron que las masas elaboradas con los sistemas aceite/gel presentaron una menor resistencia a la deformación, siendo menos elásticas y más fluidas que la masa control. Los diferentes grados de metoxil e hidroxipropil sustitución de las celulosas estudiados no afectaron al comportamiento reológico de las masas.

3. Las propiedades de viscoelasticidad lineal de las masas explican las dimensiones de las galletas tras el horneado. Las masas formuladas con el sistema aceite/gel caracterizadas por su mayor fluidaz y menor elásticidad se expandieron más durante el horneado dando lugar a galletas de mayores dimensiones.

4. Se ha propuesto una modificación de la técnica de perfil sensorial de libre elección que permite, además de obtener información directa y espontánea de los consumidores, describir las diferencias sensoriales que los consumidores perciben en las distintas etapas de la masticación de las galletas.

5. En el diseño del sistema aceite/gel como sustituto de grasa convencional en galletas es importante la elección del hidrocoloide ya que éste afecta a las propiedades sensoriales de las galletas. El uso de goma xantana no es recomendable puesto que las galletas obtenidas son mucho más duras y secas que las galletas con la grasa convencional. En cambio, la hidroxipropilmetilcelulosa resulta adecuada ya que las galletas presentan características sensoriales de textura y sabor similares a las elaboradas con la grasa convencional.

6. En el desarrollo de galletas con contenido reducido de grasa saturada, además de evaluar parámetros instrumentales como la fuerza de rotura y/o de resistencia a la penetración relacionados con la dureza de la galleta, es importante tener en cuenta el número de microfracturas (< 0,1 N) ocurridas durante la penetración ya que este parámetro se relaciona directamente con las sensaciones de desmigabilidad y arenosidad, características de las galletas elaboradas con grasa convencional.

7. Existen diferencias en la preferencia de los consumidores respecto a las galletas elaboradas con los sistemas aceite de girasol/ hidroxipropilmetilcelulosa, aceite de oliva/ hidroxipropilmetilcelulosa y con la grasa convencional que se pueden explicar de acuerdo a la relevancia que tienen los distintos atributos sensoriales para cada grupo de consumidores.

8.. El efecto de la sustitución de la grasa saturada por los distintos sistemas de aceite/ hidroxipropilmetilcelulosa en la aceptabilidad de las galletas depende del nivel de grasa. Para un contenido de grasa de 15,6%, la sustitución es posible sin que la aceptabilidad se vea afectada mientras que, para un nivel de grasa del 10,6%, la sustitución implica un descenso en la aceptabilidad de las galletas.

9. En general, el sistema aceite de oliva/ hidroxipropilmetilcelulosa se presenta como la mejor alternativa para sutituir la grasa convencional en galletas ya que las caracteristicas sensoriales que proporciona a las mismas gustan más a los consumidores que las de las galleta elaboradas con los sistemas aceite de girasol/ hidroxipropilmetilcelulosa.

10. La información relativa a la elaboración de galletas con aceite de oliva o de girasol y al bajo contenido en grasa saturada en la etiqueta de las galletas hace que los consumidores las consideren mucho más saludables y también más apetecibles que las elaboradas con grasa convencional.

11. Cuando el consumidor dispone del producto y de la etiqueta, tanto la información como el nivel de agrado que proporciona la galleta al consumirla influyen en su aceptabilidad. En el caso de las galletas con bajo contenido en grasa (10,6%), las características sensoriales no son del agrado del consumidor y la información relativa a la elaboración con aceite vegetal y al bajo contenido en grasa saturada no es capaz de incrementar lo suficiente la aceptabilidad del producto. En el caso de las galletas elaboradas con aceite de oliva y con un contenido en grasa del 15,6% cuyas características sensoriales gustan a los consumidores, la declaración en la etiqueta de su elaboración con aceite de oliva incrementa significativamente la aceptabilidad.