DISEÑO DE ALIMENTOS SACIANTES: ESTUDIO DE LAS PROPIEDADES FÍSICAS, SENSORIALES Y DE LA CAPACIDAD SACIANTE ESPERADA EN UN POSTRE LÁCTEO SÓLIDO TIPO TARTA DE QUESO

TESIS DOCTORAL

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Valencia, septiembre de 2015

Dña. Susana Fiszman Dal Santo, Profesora de Investigación del Instituto de Agroquímica y Tecnología de Alimentos de la Agencia Estatal Consejo Superior de Investigaciones Científicas

HACE CONSTAR QUE:

El trabajo de investigación titulado **"Diseño de alimentos saciantes: Estudio de las propiedades físicas, sensoriales y de la capacidad saciante esperada en un postre lácteo sólido tipo tarta de queso"** que presenta Dña. Johanna María Marcano Rodríguez por la Universidad Politécnica de Valencia, ha sido realizado en el Instituto de Agroquímica y Tecnología de alimentos (IATA-CSIC) bajo mi dirección y que reúne las condiciones para optar al grado de Doctor.

Valencia, septiembre de 2015

Fdo: Dra. Susana Fiszman Dal Santo

Para y por Angelita, quien pasó como mágica estrella fugaz, dejando sembradas las semillas del amor por la vida, el saber y el aprender, huella imborrable y un manto de sagrada protección sobre sus dos niñas…

Agradecimientos

A Dios, por nutrirme como fuente de amor, seguridad y protección, por llevarme en sus brazos aligerando mi carga en los momentos en que lo he necesitado.

A mi Directora Susana Fiszman, por ser la mejor fuente de inspiración y admiración, gran apoyo y segura mano amiga; por formar parte de mis más grandes afectos.

A mi padre Douglas Eduardo, por haberme proporcionado las herramientas necesarias para afrontar la vida, por enseñarme a volar, por participar y disfrutar del camino que me ha llevado a la consecución de todos mis sueños; por eso y mucho mas este logro también es suyo.

A mi hermana María Alejandra, por ser siempre razón y motor para lograr objetivos, por existir en mi vida, brindarme su amistad, amor y apoyo incondicional.

A mi esposo Leduar, por el amor y el apoyo ofrecido, por compartir la calidez de nuestro hogar y ser razón de mi felicidad junto a nuestros niños.

A Jesús Alberto, por la solidez, dulzura e incondicionalidad de su amistad.

A mi amiga María Alejandra y a mi cuñado Sam, por todo el apoyo y el cariño ofrecido.

A Claudia, Georgina, Sisy, Blanca y Mary Jane, por disfrutar y compartir nuestros logros y afecto, sin importar la distancia que nos separe.

A mi tutora Isabel Hernando por toda la colaboración brindada en pro de la culminación de este proyecto.

A los estudiantes que de algún modo compartieron y participaron en la fase de trabajo experimental (Sara, María Joao, Ana Karina, Diana, Dimitar, Olga y Gema).

A trabajadores y colaboradores del Instituto de Agroquímica y Tecnología de Alimentos y a estudiantes y personal de la Universidad Politécnica de Valencia, quienes participaron activamente en las diferentes pruebas de evaluación sensorial efectuadas.

Al Ministerio de Economía y Competitividad de España por la financiación prestada.

A todos los trabajadores de la Universidad Politécnica de Valencia, por su valiosa y eficaz gestión, por recibirme y compartir esta fase de consolidación académica.

Y finalmente pero no menos importante, a todo el personal del Consejo Superior de Investigaciones Científicas y del Instituto de Agroquímica y Tecnología de Alimentos, por acogerme como parte de sí y brindarme toda su colaboración.

Resumen

El desarrollo de alimentos con mayores propiedades saciantes saludables, aceptables y de uso cotidiano, representa una importante contribución en la lucha contra la obesidad y el control del peso. Sin embargo, reformular alimentos para incrementar su capacidad saciante no es una tarea fácil, debido a los múltiples factores que influyen sobre esta funcionalidad. La "cascada de la saciedad" ofrece puntos de referencia que permiten orientar el enfoque para las reformulaciones. Entre ellos, en las etapas preprandrial y prandrial tienen lugar una serie de experiencias subjetivas a nivel cognitivo y sensorial; influenciadas entre otros factores, por la calidad y la cantidad de los alimentos, que afectan las expectativas sobre la saciedad, que a su vez desempeña un papel fundamental en la saciedad fisiológica luego del consumo.

El objetivo central de este proyecto se centró en el desarrollo de diversas estrategias para la reformulación de un alimento que resulte saciante. Se evaluó el efecto de diversos factores de composición, fisicoquímicos y sensoriales en pasteles de queso como modelo de alimento sólido, sobre las expectativas de su capacidad saciante y sobre el comportamiento gástrico *in vitro.*

El pastel de queso utilizado como modelo de estudio es un postre lácteo refrigerado, compuesto básicamente por queso fresco, huevos, azúcar, leche y almidón de maíz. Su elección se fundamentó en la conveniente composición que posee tanto a nivel nutricional (base proteica) como tecnológico, ya que permitió realizar variaciones en sus ingredientes e incluir nuevos sin distorsionar radicalmente las características que determinan su naturaleza.

En una primera fase, se reformularon pasteles de queso modificando el contenido de sus componentes minoritarios (huevo, azúcar, leche y almidón de maíz) con el objetivo de evaluar, a través de los métodos de Predominio Temporal de las Sensaciones y Aceptabilidad Dinámica y Estática, el efecto de cada uno de estos ingredientes sobre la dinámica de la trayectoria oral y su relación con las expectativas de saciedad y aceptación. También se evaluaron, a través del uso de escalas bipolares "Just Abouth Right" y análisis de penalización, algunos de los atributos clave de los pasteles que determinan su aceptabilidad respecto de un "ideal". Los pasteles sin huevo y con mayor contenido en leche en polvo resultaron con texturas más duras y secas que prolongaron su exposición oral y aumentaron la capacidad saciante percibida sin afectar radicalmente su aceptabilidad.

En una segunda fase, debido a que las proteínas se reconocen como el macronutriente con mayores propiedades saciantes, se realizaron reformulaciones incorporando concentraciones crecientes de proteínas láctea (aislado de proteína de suero lácteo) y vegetal (concentrado de proteína de soja). Para evaluar los cambios en las propiedades físicas de los pasteles y su efecto sobre la saciedad percibida se utilizaron métodos de reología, texturometría y la técnica sensorial C.A.T.A. (*Check-all-That-Apply*). Con el aumento en la concentración de proteína añadida en los pasteles, se observaron incrementos en las propiedades viscoelásticas de las mezclas batidas y en los valores de dureza y masticabilidad instrumental después del horneado. Los pasteles con aislado de proteína de suero lácteo resultaron más duros y compactos que los pasteles con proteína de soja. La proteína de soja confirió características de sabor "no esperadas" resultando en una menor aceptabilidad y expectativas de saciedad.

En una tercera etapa, se evaluó el efecto de incrementar la complejidad en textura y apariencia de los pasteles de queso, incorporando distintas partículas visibles (copos de avena, salvado de trigo, semillas de lino y coco rallado), sobre las expectativas de saciedad. Se utilizaron texturometría y la técnica de Flash Profile para la caracterización sensorial. Mediante técnica de preguntas abiertas se exploraron los términos asociados con la percepción de complejidad. Los pasteles con copos de avena fueron más duros, difíciles de masticar y obtuvieron los mayores valores de saciedad esperada, confirmando los resultados de las fases uno y dos de la presente memoria. El resto de los pasteles con partículas añadidas no presentaron diferencias significativas de dureza y masticabilidad instrumental. En éstos, se encontró que a mayor percepción de complejidad mayor valoración de su capacidad saciante. Los términos relacionados con la falta de homogeneidad de la textura, la apariencia y la presencia de partículas se mencionaron con mayor frecuencia para evaluar la complejidad de las muestras. En consecuencia, los pasteles con salvado de trigo, seguidos de los que contenían semillas de lino (partículas oscuras y de tamaño bien visible) se percibieron como más complejos que los pasteles con coco rallado (partículas blancas, pequeñas y bien integradas en la masa del pastel).

En una cuarta fase del proyecto, considerando la importancia de los mecanismos de distensión y vaciado gástrico involucrados en los procesos preabsortivos, se elaboraron pasteles incorporando concentraciones crecientes de glucomanano de konjac (KGM) que es una fibra soluble de muy alta viscosidad. La presencia de esta fibra permitió de forma colateral el uso de queso desnatado (con la consiguiente eliminación de toda la grasa láctea) y la supresión del almidón de maíz de las formulaciones. Se evaluó el comportamiento viscoelástico de los pasteles digeridos bajo condiciones gástricas *in vitro* utilizando técnicas de reología instrumental. El aumento en la concentración de KGM en los pasteles de queso digeridos, incrementó gradualmente las propiedades viscoelásticas. A las dos concentraciones más bajas, demostró su contribución como sustituto tecnológico y funcional de la grasa láctea y del almidón de maíz y a concentraciones altas se observaron incrementos radicales en las componentes viscoelásticas, demostrando la formación de una masa de características sólidas y que podría provocar distensión gástrica y el consiguiente retraso del vaciado. El KGM en los pasteles resultó más efectivo que el ingrediente en solitario. Por otra parte, los pasteles formulados con KGM mostraron mayor dureza y masticabilidad instrumentales lo que evidenció beneficios adicionales ya mencionados a nivel orosensorial. En cuanto a la aceptabilidad, el ingrediente disminuyó la intensidad del sabor percibido, por lo que las futuras reformulaciones deben reorientar el sabor.

Finalmente, como estudio integrador de los resultados obtenidos con todas las estrategias anteriores, se utilizó la técnica sensorial de Mapas Proyectivos Parciales y su comparación con el Mapa Global. Se caracterizaron y compararon diferentes formulaciones obtenidas en las cuatro fases anteriores: la básica, con proteína de soja, con proteína láctea, sin huevo, sin azúcar, sin almidón, con salvado de trigo y con glucomanano de konjac. Los mapas parciales permitieron explorar la percepción de los consumidores para reunir información acerca de las modalidades sensoriales específicas de textura y sabor separadamente. Los resultados indicaron que con los mapas parciales se obtuvo información más detallada, permitiendo que los consumidores se centren en un foco perceptual más reducido. El mapa global mostró mayor correlación con el mapa de sabor, lo que indica que los consumidores se centraron en esta modalidad para encontrar similitudes y diferencias entre muestras, o al menos les resultó más sencillo, permitiendo diferenciar entre muestras con sabores más y menos familiares. La capacidad saciante se alineó con texturas más duras pero sin perder sabores tradicionales reconocibles en un pastel de queso. La comparación de mapas proyectivos resultó ser un aporte integrador muy interesante en el diseño de nuevas categorías de productos como los alimentos saciantes.

Resum

El desenvolupament d'aliments amb propietats saciants saludables, acceptables i d'ús quotidià, representa una important contribució en la lluita contra l'obesitat i el control del pes. No obstant açò, reformular aliments per a incrementar la seua capacitat saciant no és una tasca fàcil, a causa dels múltiples factors que influeixen sobre aquesta funcionalitat. La “cascada de la sacietat” ofereix punts de referència que permeten orientar l'enfocament per a les reformulacions. Entre ells, en les etapes preprandrial i prandrial tenen lloc una sèrie d'experiències subjectives a nivell cognitiu i sensorial; influenciades entre altres factors, per la qualitat i la quantitat dels aliments, que afecten les expectatives sobre la sacietat, que al seu torn exerceix un paper fonamental en la sacietat fisiològica després del consum.

L'objectiu central d'aquest projecte es va centrar en el desenvolupament de diverses estratègies per a la reformulació d'un aliment que resulte saciant. Es va avaluar l'efecte de diversos factors de composició, fisicoquímics i sensorials en pastissos de formatge com a model d'aliment sòlid, sobre les expectatives de la seua capacitat saciant i sobre el comportament gàstric in vitro.

El pastís de formatge utilitzat com a model d'estudi és un postre làctic refrigerat, compost bàsicament per formatge fresc, ous, sucre, llet i midó de dacsa. La seua elecció es va fonamentar en la convenient composició que posseeix tant a nivell nutricional (base proteica) com a tecnològic, ja que va permetre realitzar variacions en els seus ingredients i incloure nous sense distorsionar radicalment les característiques que determinen la seua naturalesa.

En una primera fase, es van reformular pastissos de formatge modificant el contingut dels seus components minoritaris (ou, sucre, llet i midó de dacsa) amb l'objectiu d'avaluar, a través dels mètodes de Predomini Temporal de les Sensacions i Acceptabilitat Dinàmica i Estàtica, l'efecte de cadascun d'aquests ingredients sobre la dinàmica de la trajectòria oral i la seua relació amb les expectatives de sacietat i acceptació. També es van avaluar, a través de l'ús d'escales bipolars “Just About Right” i anàlisis de penalització, alguns dels atributs clau dels pastissos que determinen la seua acceptabilitat respecte d'un “ideal”. Els pastissos sense ou i amb major contingut en llet en pols van resultar amb textures més dures i seques que van perllongar la seua exposició oral i van augmentar la capacitat saciant percebuda sense afectar radicalment la seua acceptabilitat.

En una segona fase, a causa que les proteïnes es reconeixen com el macronutrient amb majors propietats saciants, es van realitzar reformulacions incorporant concentracions creixents de proteïnes làctiques (aïllat de proteïna de sèrum làctic) i vegetal (concentrat de proteïna de soia). Per a avaluar els canvis en les propietats físiques dels pastissos i el seu efecte sobre la sacietat percebuda es van utilitzar mètodes de reologia, textura i la tècnica sensorial C.A.T.A. (*Check-all-That-Apply*). Amb l'augment en la concentració de proteïna afegida en els pastissos, es van observar increments en les propietats viscoelàstiques de les mescles batudes i en els valors de duresa i mastegabilitat instrumental després del enfornat. Els pastissos amb aïllat de proteïna de sèrum làctic van resultar més durs i compactes que els pastissos amb proteïna de soia. La proteïna de soia va conferir característiques de sabor “no esperades” resultant en una menor acceptabilitat i expectatives de sacietat.

En una tercera etapa, es va avaluar l'efecte d'incrementar la complexitat en textura i aparença dels pastissos de formatge, incorporant diferents partícules visibles (flocs de civada, salvat de blat, llavors de lli i coco rallat), sobre les expectatives de sacietat. Es van utilitzar texturometria i la tècnica de *Flash Profile* per a la caracterització sensorial. Mitjançant tècnica de preguntes obertes es van explorar els termes associats amb la percepció de complexitat. Els pastissos amb flocs de civada van ser més durs, difícils de mastegar i van obtenir els majors valors de sacietat esperada, confirmant els resultats de les fases un i dues de la present memòria. La resta dels pastissos amb partícules afegides no van presentar diferències significatives de duresa i mastegabilitat instrumental. En aquests, es va trobar que a major percepció de complexitat major valoració de la seua capacitat saciant. Els termes relacionats amb la falta d'homogeneïtat de la textura, l'aparença i la presència de partícules es van esmentar amb major freqüència per a avaluar la complexitat de les mostres. En conseqüència, els pastissos amb segó de blat, seguits dels quals contenien llavors de lli (partícules fosques i de grandària ben visible) es van percebre com més complexos que els pastissos amb coco rallat (partícules blanques, xicotetes i ben integrades en la massa del pastís).

En una quarta fase del projecte, considerant la importància dels mecanismes de distensió i buidatge gàstric involucrats en els processos preabsortius, es van elaborar pastissos incorporant concentracions creixents de glucomanan de konjac (KGM) que és una fibra soluble de molt alta viscositat. La presència d'aquesta fibra va permetre de forma col·lateral l'ús de formatge descremat (amb la conseqüent eliminació de tot el greix làctic) i la supressió del midó de dacsa de les formulacions. Es va avaluar el comportament viscoelàstic dels pastissos digerits sota condicions gàstriques in vitro utilitzant tècniques de reologia instrumental. L'augment en la concentració de KGM en els pastissos de formatge digerits, va incrementar gradualment les propietats viscoelàstiques. A les dues concentracions més baixes, va demostrar la seua contribució com a substitut tecnològic i funcional del greix làctic i del midó de dacsa i a concentracions altes es van observar increments radicals en les components viscoelàstics, demostrant la formació d'una massa de característiques sòlides i que podria provocar distensió gàstrica i el conseqüent retard del buidatge. El KGM en els pastissos va resultar més efectiu que l'ingredient en solitari. D'altra banda, els pastissos formulats amb KGM van mostrar major duresa i mastegabilitat instrumentals el que va evidenciar beneficis addicionals ja esmentats a nivell oro-sensorial. Respecte a l'acceptabilitat, l'ingredient va disminuir la intensitat del sabor percebut, per la qual cosa les futures reformulacions han de reorientar el sabor.

Finalment, com a estudi integrador dels resultats obtinguts amb totes les estratègies anteriors, es va utilitzar la tècnica sensorial de Mapes Projectius Parcials i la seua comparació amb el Mapa Global. Es van caracteritzar i van comparar diferents formulacions obtingudes en les quatre fases anteriors: la bàsica, amb proteïna de soia, amb proteïna làctica, sense ou, sense sucre, sense midó, amb segó de blat i amb KGM. Els mapes parcials van permetre explorar la percepció dels consumidors per a reunir informació sobre les modalitats sensorials específiques de textura i sabor separadament. Els resultats van indicar que amb els mapes parcials es va obtenir informació més detallada, permetent que els consumidors se centren en un focus perceptual més reduït. El mapa global va mostrar major correlació amb el mapa de sabor, la qual cosa indica que els consumidors es van centrar en aquesta modalitat per a trobar similituds i diferències entre mostres, o almenys els va resultar més senzill, permetent diferenciar entre mostres amb sabors més i menys familiars. La capacitat saciant es va alinear amb textures més dures però sense perdre sabors tradicionals reconeguts en un pastís de formatge. La comparació de mapes projectius va resultar ser una aportació integradora molt interessant en el disseny de noves categories de productes com els aliments saciants.

Abstract

The development of healthy, acceptable food with enhanced satiating properties contributes importantly in weight control and tackling obesity. However, reformulating food to increase satiating capacity is not an easy task since multiple factors influence food characteristics. The "satiety cascade" provides landmarks for several approaches for reformulation. Among them, in both the pre-prandial and prandial steps, subjective experiences are important at cognitive and sensorial levels; quality and quantity of food affect satiety expectations, which in turn play a fundamental role in the physiological satiety after consumption.

The main objective of this project was the development of various strategies for the reformulation of satiating food. The effects of composition, physical-chemical and sensory factors of a solid model food (cheese pie), on the expectations of its satiating capacity and *in vitro* gastric behaviour were evaluated.

Fresh-cheese pie was used as a model food for the complete study. It is a refrigerated dairy dessert basically made of fresh cheese, eggs, sugar, milk, and corn starch. This choice was based on its convenient composition and both from a nutritional (protein based) and technological point of view since it allowed variations in the proportion of ingredients and the addition of new ones without distorting its nature radically.

In a first phase, cheese pie was reformulated changing the content of its minor components (egg, sugar, milk, and corn starch) in order to assess the effect of each ingredient on the dynamics of the oral pathway and its relation to the expectations of satiety and acceptance; Temporal Dominance of Sensations and Acceptability (both Dynamic and Static)

were applied. The pies were also evaluated, through the use of bipolar scales “Just About Right" and Penalty Analysis on some of their key attributes for determining their adequacy. The cheese pies without egg and with addition of extra milk powder were harder and drier that prolonged the oral exposure and increased the satiating capacity perceived without affecting importantly their acceptability.

In a second phase, given that proteins are recognized as the macronutrient with the greatest satiating properties, reformulations were made increasing the concentration of dairy protein (whey isolate) and vegetable protein (soy concentrate). To evaluate changes in the physical properties of the cheese pies and their effect on satiety perceived, rheological and texture methods, and CATA (Check-all-that-apply) sensory techniques were used. The viscoelastic properties of the pie batters and instrumental hardness and chewiness values of the baked pies rose with increasing protein concentration. The cheese pies with whey protein isolated were harder and more compact than the pies with soy protein. Soy protein conferred flavour characteristics "unexpected" resulting in a lower acceptability and expectations of satiety.

In a third step, the effect of increasing complexity in appearance and texture of cheese pies by incorporating various visible particles (oat flakes, wheat bran, flax seeds and grated coconut), on expectations of satiety was evaluated. Instrumental texture and Flash Profile technique for sensory characterization were used. In addition, open-ended questions for terms associated with the perception of complexity were explored. The pies with oat flakes were harder and more difficult to chew, and obtained the highest values of expected satiating capacity, confirming the results of the two previous studies. The rest of the cheese pies did not present significant differences in instrumental hardness and chewiness values. In these pies it was found that when the perception of complexity was greater, also the appreciation of satiating capacity was greater. Consequently, pies with wheat bran, followed by pies with flax seed (both with dark particles of visible size) were perceived as more complex than the cheese pies with coconut (white, small and fine particles embedded in the crumb of pie). The terms related with the texture and appearance homogeneity, and with the presence of particles were the most frequently mentioned in an open-question task about complexity appreciation.

In a fourth phase of the project, considering the importance of the mechanisms involved in gastric distention and emptying as pre-absorptive processes, cheese pies were prepared incorporating increasing concentrations of konjac glucomannan (KGM) which is a soluble fibre with high viscosity. The presence of this fibre collaterally allowed the use of skimmed cheese (with the consequent elimination of all cheese fat) and the corn starch suppression. The viscoelastic behaviour of pies with increasing KGM contents, digested under *in vitro* gastric conditions, was evaluated. When the concentration of KGM rose in the pies, also the viscoelastic properties of pies digested increased. At the two lower concentrations, KGM showed it contribution as technological and functional substitute of cheese fat and corn starch. At high concentrations of KGM, dramatic increases in the viscoelastic functions were observed, showing the formation of a mass of solid features that could cause distention and the consequent delay in gastric emptying. The KGM in pies was more effective than the ingredient alone. Moreover, pies with KGM had higher instrumental hardness and chewiness values with the additional benefits at orosensorial level. Regarding the acceptability, KGM caused decrease in the intensity of flavour perceived, so that future reformulations should redirect flavour adjustment.

Finally, as an integrating study of the results obtained with all previous strategies, sensory techniques Partial Projective Maps and comparison with the Global Map were used. Different formulations obtained in the previous four phases: basic, added with soy protein added with milk protein, with no eggs, with no sugar, with no starch, added with wheat bran and added with konjac glucomannan were characterized and compared. Partial maps explored the perception of consumers to collect information about sensory modalities specific of texture and flavour separately. The results indicated that with the partial maps more detailed information was obtained, allowing consumers to focus on a smaller perceptual focus. The global map showed higher correlation with the map of flavour, indicating that consumers focused in flavour to find similarities and differences between samples, or at least found it easier, and allowing differentiation between samples with more and less familiar flavours. The satiating capacity aligned with harder textures without losing recognizable traditional flavours in a cheese pie. Comparison of projective maps proved to be a very interesting design of new product categories as satiating foods.

ÍNDICE

INTRODUCCIÓN

1. APETITO, PLENITUD Y SACIEDAD

La **sensación de apetito** es la motivación interna que conduce a una persona a buscar comida, seleccionarla y consumirla (De Graaf *et al.*, 2004). Su expresión es el resultado de la regulación biológica (incluyendo factores fisiológicos y psicológicos) y de la adaptación al entorno. Algunos factores fisiológicos son, entre otros, edad, sexo, peso corporal y nivel de actividad física, y entre los factores psicológicos se encuentran, por ejemplo, el estado de ánimo, experiencias previas o restricciones y desórdenes alimentarios. Por último, entre los factores del entorno son destacables los patrones o estilos de vida, los hábitos alimentarios, la cultura del entorno familiar y del sitio en que se habite, influencias estacionales, efecto de música y televisión, momento del día y la presencia de otras personas durante las comidas.

El mundo académico diferencia claramente entre la sensación de **plenitud** (“satiation” en idioma inglés) y la **saciedad** (“satiety”). La primera es la sensación que conduce a dejar de comer durante una comida y suele ir acompañada de una sensación de satisfacción, mientras que la segunda es la sensación de “estar satisfecho” que aparece después de una comida suprimiendo la voluntad de ingerir alimentos y persiste hasta que retorna el hambre. Ambas forman parte del complejo sistema de control del apetito que regula cuándo y cuánto comer (Benelam, 2009).

Blundell *et al*. (1987) propusieron un esquema denominado la **“Cascada de la Saciedad”**, para resumir los factores temporales que regulan la ingesta de alimentos desde el momento anterior a la comida hasta la posterior saciedad. Esta cascada muestra la existencia de señales preingestivas (sensoriales y cognitivas), postingestivas y postabsortivas (Figura 1). Investigaciones posteriores han enriquecido esta información con nuevos aportes (Blundell, 1991; Backus, 2006; Harrold *et al*.; 2012 y Kringlebach *et al*., 2012).

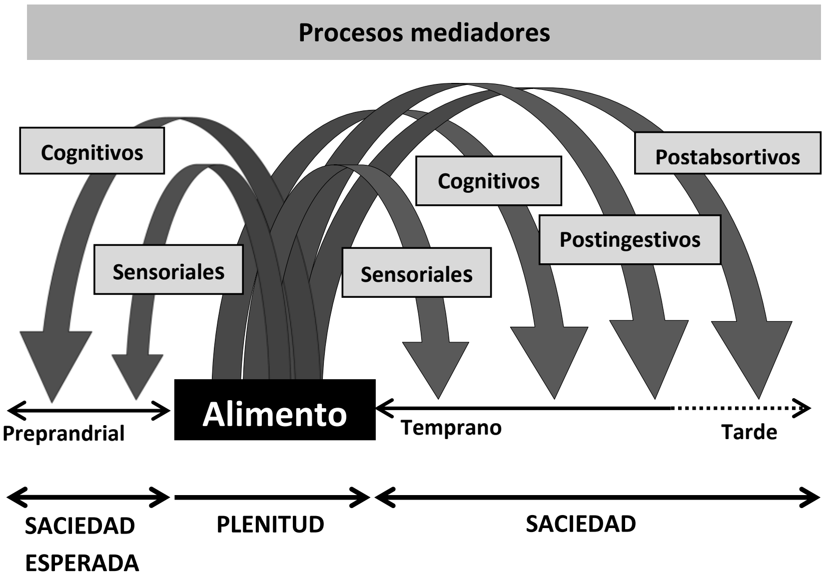

Figura 1. Cascada de la saciedad propuesta por Blundell *et al*. en 1987 (modificada).

Según se observa en la Figura 1, antes y durante la ingesta existen **factores sensoriales y cognitivos (**como la palatabilidad de las comidas, el tamaño de las porciones, la variedad o las asociaciones con experiencias previas) que determinan las expectativas de saciedad. A partir de la ingesta, una vez que el alimento llega al estómago, se desencadenan **factores postingestivos** como la distención gástrica que actúa a través del nervio vago, enviando señales al cerebro para generar la sensación de plenitud. Una vez iniciada la absorción de nutrientes en el intestino delgado se liberan diversas hormonas y promotores gástricos e intestinales actuando de modo integrado con el cerebro para producir sensaciones de plenitud y saciedad.

En el **estadio postabsortivo**, ciertos receptores especializados detectan los niveles de nutrientes enviando también señales que a través del cerebro, orquestan un complejo sistema responsable de la regulación del hambre (Blundell y Bellisle, 2013) y determina el comportamiento ante los alimentos.

2. HORMONAS DE LA SACIEDAD

La homeostasis es el conjunto de mecanismos autorregulados que aseguran un mantenimiento constante de la composición y de las propiedades internas del cuerpo humano. De este modo, las reservas de energía, estables y bien reguladas, se mantienen durante largos períodos de tiempo. Para mantener un balance en el consumo energético, se regula la termogénesis y la actividad física por medio de al menos dos sistemas separados pero interrelacionados: a) uno a corto plazo que controla el inicio y el final de las comidas dependiendo del contenido del tracto gastrointestinal y b) un sistema a largo plazo que defiende la estabilidad de las reservas de energía y, por lo tanto, del peso corporal (Spiegelman y Flier, 2001).

Se ha realizado un gran esfuerzo en la identificación de los diversos sistemas hormonales y neurales mediante los cuales el cerebro se informa sobre la disponibilidad de los nutrientes ingeridos y almacenados y, a su vez, genera respuestas autonómicas, endocrinas y de comportamiento. Se han señalado áreas del córtex cerebral y el sistema límbico que también son importantes en el procesamiento de la información relacionada con las experiencias previas con alimentos, recompensas y emociones, así como con el contexto social y ambiental (Berthoud y Morrison, 2008). Estudios recientes parecen demostrar que durante la ingestión de nutrientes se activa una red bien definida de áreas cerebrales, haciendo posible el estudio de la modulación de esta red mediante factores psicológicos tales como las emociones (Aziz, 2012).

Entre las hormonas relacionadas con la regulación del apetito más destacadas se encuentran la leptina, producida en el tejido adiposo y la insulina que es una hormona metabólica que se produce en el páncreas. A diferencia de la leptina que no aumenta directamente en relación con la ingesta, la secreción de insulina sí ocurre rápidamente luego de las comidas y actúa regulando los niveles de glucosa en sangre (Benelam, 2009). Kieffer y Habener (2000) han sugerido que la insulina podría desempeñar un papel estimulante sobre la producción de leptina.

TABLA 1. Hormonas gastrointestinales (tomado de: Benalam, 2009).

Nombre	Sitio de producción	Efecto sobre el apetito	Efectos adicionales
Grelina	Estómago	Aumenta el hambre	✓ Efecto a largo plazo sobre el balance energético
Colecistoquinina (CCK)	Duodeno y yeyuno	Aumenta la plenitud	✓ Retrasa el vaciado gástrico ✓ Estimula la secreción de enzima pancreática ✓ Estimula la contracción de la vesícula biliar ✓ Actúa como un neurotransmisor
Glucagón péptido 1 (GLP-1)	Intestino y cerebro	Aumenta la saciedad	✓ Estimula la producción de insulina ✓ Retrasa el vaciado gástrico
Oxitomodulina (OXM)	Intestino y cerebro	Aumenta la saciedad	✓ Retrasa el vaciado gástrico
Péptido YY (3-36) (PYY 3-36)	Íleon, colon y recto	Aumenta la saciedad	✓ Retrasa el vaciado gástrico y el tránsito intestinal ✓ Reduce las secreciones gástricas
Polipéptido pancreático (PP)	Pancreas	Aumenta saciedad	

3. MACRONUTRIENTES Y PODER SACIANTE

Los macronutrientes presentes en los alimentos influyen de distinta manera en los mecanismos fisiológicos que regulan el apetito. Igual cantidad de calorías obtenidas a partir de diferentes macronutrientes afectan de distinta manera a la saciedad. A su vez, lógicamente la composición influye sobre las propiedades físicas de los alimentos, afectando su densidad energética, la palatabilidad, textura, estructura y vida útil, entre otros factores. Es por ello que la variación en la calidad y cantidad de macronutrientes es una herramienta importante para formular alimentos saciantes que contribuyan al control de peso y tratamiento de la obesidad (Fiszman y Varela, 2013).

En general es complicado extrapolar resultados universales a partir de ensayos de intervención con humanos. Esto se debe a que los estudios presentan una variabilidad muy grande en sus condiciones experimentales; tanto en los alimentos (macronutrientes, densidad energética, textura, aspecto, características hedónicas, forma de presentación, etc.), en los individuos (edad, género, índice de masa corporal, dietas restrictivas, nivel social, etc.), en la planificación (ensayos agudos o crónicos, en laboratorios, en casa) y en las medidas (nivel de hambre, hormonas, hidrógeno espirado, índice glucémico, diversas características de los alimentos, etc.).

3.1. Proteínas

Numerosos estudios han confirmado que las proteínas son el macronutrientes con mayor poder saciante. Con un mismo balance energético las comidas con un mayor contenido proteico resultan más saciantes. Este efecto se ha atribuido a la concentración de aminoácidos en sangre, involucrados en la regulación de los procesos de oxidación y en la gluconeogénesis (Aldrich *et al*., 2011; Veldhorst *et al*., 2012), a su estrecha relación con el incremento de la termogénesis (que se detecta como incrementos de temperatura corporal y de consumo de oxígeno) (Westerterp-Plantenga *et al*.,1999; Lejeune *et al*., 2006 y Westerterp-Plantenga *et al*., 2007) y a su influencia sobre las hormonas de la saciedad (Westerterp-Plantenga, 2003; Veldhorst *et al*., 2009). Sin embargo, la saciedad percibida puede incrementarse en el tiempo, cuando se consume repetidamente un alimento incluso sin variar en nada su composición (Brunstrom *et al*., 2010), lo cual confirma la existencia de factores colaterales y ajenos a la composición del alimento.

La mayor parte de los estudios con humanos que analizan las proteínas como componente saciante se basan en dietas completas con alto contenido en proteínas y no en un único alimento enriquecido. De hecho en el mercado existen gamas completas de alimentos variados ricos en proteínas que se comercializan bajo una misma marca comercial

Algunos trabajos sugieren que el tipo de proteína puede influir de manera diferente sobre la capacidad saciante. Uhe, *et al.* (1992) aportaron resultados que apuntaban hacia una mayor saciedad luego de la ingesta de pescado, en lugar de carne de res o de pollo; Mikkelsen *et al*. (2000) realizaron un estudio con 12 hombres obesos, encontrando que el consumo de una dieta a base de carne de cerdo se tradujo en un mayor gasto energético en comparación con el consumo de una dieta a base de proteína de soja. Estos resultados sugieren que el efecto de las proteínas sobre la termogénesis, podría estar relacionado con el valor biológico o calidad de la proteína ingerida. En cuanto a las proteínas lácteas, los resultados son diversos, algunos autores han encontrado mayor capacidad saciante en las proteínas del suero lácteo (Hall *et al*., 2003) y otros en la caseína (Boirie *et al*., 1997; Acheson *et al*., 2011; Alfenas *et al*., 2011). Algunos estudios que combinan ambos tipos indican que en conjunto podrían potenciar sus efectos individuales y brindar mejores resultados que por separado (Diepvens *et al*. 2008).

3.2. Fibras

La habilidad que tienen las fibras solubles para producir mezclas viscosas en el tracto gastrointestinal contribuyen a la distensión gástrica y retrasa el vaciado gástrico (Slavin, 2005), prolongando el tiempo para la absorción de nutrientes y para la generación de señales postabsortivas promotoras de la saciedad (Nilsson *et al*., 2008).

Las propiedades de textura de algunas fibras, sobre todo las insolubles como el salvado de trigo o los cereales en granos integrales incrementarían la fuerza y tiempo de masticación, promoviendo la secreción de saliva y jugos gástricos, lo cual junto con sus tendencia a incrementar el volumen –debido a su alta capacidad de retención de agua– también contribuyen a la distensión gástrica (Slavin y Green, 2007).

Por último, existe un tercer mecanismo de acción de las fibras sobre la saciedad, y es que pueden ser fermentadas en el colon (Wanders *et al.* 2011). Por definición todas las fibras dietarias pasan a través del intestino delgado sin digerirse; aun así, sin embargo al llegar al colon, pueden ser fermentadas por bacterias anaeróbicas, produciendo ácidos grasos de cadena corta. Estos metabolitos a su vez pueden ser promotores de efectos saciantes, debido a su implicación en numerosos mecanismos post-absortivos. En general, las fibras solubles (pectinas, los almidones resistentes, gomas y polifructosas como la inulina) son más fermentables que las insolubles (Sleeth *et al*., 2010).
Debe señalarse que en estudios comparativos hechos para distintos tipos de fibras existen amplias diferencias en los resultados debido, además de las razones ya apuntadas, a la falta de control de su viscosidad, de su capacidad de gelificación, de su solubilidad en el tracto gastrointestinal, de sus perfiles de fermentación (Lyly *et al*., 2009).

3.3. Hidratos de carbono

También para los hidratos de carbono existe un buen número de investigaciones con resultados muy diversos realizadas en un amplio grupo de sustancias; por esta razón, se hace difícil llegar a un consenso sobre sus efectos reales sobre la saciedad. Por la importancia del consumo de azúcar, quizás la vertiente más estudiada se enfoca al estudio de las respuestas glucémicas de los alimentos y su impacto sobre el control de peso. En una revisión efectuada por Bornet *et al.* (2007), que incluyó el análisis de 26 estudios clínicos, los autores concluyeron que existe evidencia suficiente para reconocer un mayor efecto saciante en los alimentos con bajo índice glucémico; sin embargo, se mencionaron una serie de variables no controladas como el contenido de fibra de los alimentos o su palatabilidad, que impiden una visualización clara de la generalización como consecuencia de los resultados.

3.4. Grasas

El efecto positivo de las grasas sobre la palatabilidad de los alimentos, junto a su alto impacto sobre la densidad energética suele influir negativamente sobre su uso en el desarrollo de alimentos con capacidad saciante. Por lo tanto se convierten en un ingrediente poco aconsejable para su uso en productos que están enfocados normalmente también al control de peso. Aun así, Maljaars *et al.* (2008) aportan la idea de que las emulsiones de grasas no digeribles actúan a corto plazo sobre el control de la ingesta debido a su posible efecto indirecto sobre la secreción de péptidos gastrointestinales que promueven la saciedad. Esta teoría ha sido refutada por Chan *et al.* (2012), quienes en su estudio no hallaron ningún efecto reductor de la ingesta ni cambios en el comportamiento alimentario; solamente registraron un ligero incremento en la sensación de plenitud luego del consumo de la emulsión grasa, combinada con un yogurt lácteo semi-sólido. Cuando la emulsión se comió sola, con agua o presentada en compañía de un alimento sólido, no encontraron ningún efecto. Sin embargo, han aparecido en el mercado algunos productos de aceite fraccionado de palma y de avena en emulsión con agua con propósitos saciantes.

4. TEXTURA DE LOS ALIMENTOS Y PODER SACIANTE

La textura es una propiedad sensorial que se deriva de la composición y estructura de los alimentos a niveles moleculares, micro- y macroscópicos; su percepción puede involucrar uno o varios tipos de estímulos trabajando en conjunto varios sentidos (táctiles, visuales, auditivos y relacionados con la cinestesia). El procesamiento oral es el estadio más importante para la percepción y apreciación de la textura e involucra una serie de complejas operaciones que incluyen desde el primer mordisco, transporte dentro de la boca y masticación, mezclado del alimento con la saliva para lograr la formación del bolo y finalmente la deglución segura y confortable (Chen, 2009).

Se han realizado numerosos estudios para conocer los procesos involucrados en la trayectoria oral de los alimentos (De Wijk *et al*., 2008; Koc *et al*., 2013; Rodrigues, 2014). Los alimentos sólidos requieren mayor trabajo de manipulación en boca antes de tragarse, produciéndose una mayor exposición orosensorial; este incremento del tiempo de permanencia favorece la recepción de las señales que permiten “medir” la capacidad nutritiva de un alimento (por experiencias previas) y evocar la sensación de plenitud que inducen la terminación de la ingesta (Hogenkamp y Schiöth, 2013). Forde *et al*. (2013), en un estudio con alimentos sólidos salados con diferentes texturas, encontraron que el incremento del tiempo de exposición oral y del número total de masticaciones se tradujo en un mayor efecto saciante.

Otros autores también han respaldado que en alimentos líquidos o semisólidos como por ejemplo en bebidas lácteas un aumento de la viscosidad, la consistencia o la cremosidad pueden influir positivamente sobre la capacidad saciante percibida: esto a su vez tiene efecto sobre las señales sensoriales y metabólicas involucradas en la producción de las sensaciones de plenitud y saciedad “reales” (McCrickerd *et al*., 2014; Yeomans y Chambers, 2011; Hogenkamp *et al*., 2011 ; Mars *et al*., 2009).

5. ESTUDIOS SOBRE PLENITUD Y SACIEDAD

La mayor parte de los estudios sobre saciedad pertenecen a la categoría de ensayos de intervención clínicos y se han enfocado a la evaluación del hambre y otras sensaciones relacionadas, durante y entre las comidas después de la administración del determinado alimento que se quiere ensayar. El ensayo más común consiste en proporcionar el alimento o sustancia denominada “precarga” y mediante el uso de escalas de visualización análogas (VAS), los sujetos puntúan el hambre, el deseo de comer, saciedad, etc. que perciben a partir del consumo y durante períodos regulares posteriores a dicho consumo. Las investigaciones frecuentemente combinan de manera conveniente estos resultados con los de una amplia gama de metabolitos en sangre (hormonas y péptidos), que suelen tomarse como índices biológicos, conjugando de este modo resultados psicológicos y fisiológicos (Stubbs *et al*., 2000).

Estos estudios generalmente se efectúan en ambientes aislados y controlados, obteniendo resultados que pueden resultar muy distantes de los recogidos en ambientes de consumo habituales reales. Debido a su enfoque clínico, buscan reducir tanto como sea posible, los estímulos provenientes del entorno y del alimento precarga para no influir sobre los aspectos sensorial y cognitivo de los sujetos (Livingstone et al, 2000).

6. MÉTODOS SENSORIALES PARA ESTUDIAR LAS EXPECTATIVAS SOBRE CAPACIDAD SACIANTE Y SU RELACIÓN CON ATRIBUTOS DE LOS PASTELES DE QUESO

6.1. Saciedad esperada

La “Saciedad Esperada", es decir, la expectativa acerca de la capacidad saciante que va a tener un alimento en el momento que se está ingiriendo, desempaña un papel importante en la saciedad “real” que se experimenta luego de su consumo; su influencia puede ser notable ya que persiste durante el intervalo entre comidas (Brunstrom *et al*., 2011).

En la presente memoria, con el fin de estimar la capacidad saciante esperada de los alimentos experimentales (pasteles de queso de diversas formulaciones), los participantes puntuaron en una escala de nueve puntos, la sensación de saciedad que creían que les proporcionaría dicho pastel si consumieran una cantidad determinada. Para ello, las muestras proporcionadas a los panelistas se obtuvieron cortando en 6 cuñas triangulares los pasteles (de forma circular de 8 cm de diámetro), lo cual les permitió la visualización de forma fácil e intuitiva de cuál sería la ración completa propuesta.

6.2. Otros métodos sensoriales

Se utilizaron varios métodos de evaluación sensorial con consumidores para relacionar una serie de atributos sensoriales y de consumo con los resultados de capacidad saciante esperada correspondientes, y que permitieron:

- ✓ Determinar y evaluar los atributos sensoriales característicos de los pasteles reformulados (Flash Profile y Check All That Apply Questions, C.A.T.A.)

- ✓ Observar la aparición y evolución de los atributos sensoriales durante el tiempo (Predominio Temporal de las Sensaciones),

- ✓ Conocer la aceptabilidad global y la aceptabilidad dinámica a lo largo del tiempo de consumo (Aceptabilidad estática y dinámica),

- ✓ Analizar la adecuación de determinados atributos en escalas bipolares “just-about-right” (JAR) por medio del Análisis de Penalización que permite conocer la dirección de los cambios a efectuar en la reformulación.

- ✓ Explorar la percepción del consumidor sobre la apreciación de la complejidad en apariencia y en textura de los pasteles reformulados (Preguntas abiertas) y

- ✓ Analizar la percepción de los consumidores sobre diferentes formulaciones (Mapas proyectivos parciales y global).

A continuación se comentan los métodos más novedosos.

6.2.1. Flash profile (FP)

Es un método muy flexible que permite elaborar en forma rápida un perfil que caracteriza al producto de acuerdo con sus más sobresalientes atributos sensoriales (Varela y Ares, 2012).

Consiste en dos fases que pueden hacerse en una misma sesión o en dos diferentes. Las muestras se presentan todas en conjunto a la vez; en la primera fase, los participantes las prueban comparativamente y generan todos los atributos que consideran que las diferencian; en la segunda fase, deben ordenar las muestras desde un nivel “bajo” hasta un nivel “alto” de cada atributo propuesto en la primera fase (Dairou y Sieffermann, 2002).

6.2.2. Check All that Apply Questions (C.A.T.A.)

El método de C.A.T.A. consiste en hacer una lista consensuada de atributos sensoriales o características de otra índole (uso, hedónicas, etc.) que resulten interesantes de valorar para un producto en particular. Esta lista se presenta a los participantes junto con las muestras para que marquen cuáles de los atributos o características las describen Es una alternativa rápida y menos costosa en comparación con los tradicionales análisis sensoriales de tipo descriptivo cuantitativo, que permite una caracterización eficiente de productos. Algunos autores han demostrado que los resultados obtenidos a través de este método son muy similares a los obtenidos con paneles entrenados (Ares *et al*.; 2010, Bruzzone *et al*., 2012; Doodley *et al*, 2010). También se ha encontrado que los consumidores consideran este tipo de test como de fácil respuesta (Ares *et al*., 2011).

6.2.3. Predominio temporal de las sensaciones (TDS)

El método del predominio temporal de las sensaciones (TDS) ha sido empleado para estudiar cuáles son los atributos sensoriales de mayor impacto (que predominan sobre los demás) y su evolución en el tiempo durante la ingesta. Permite evaluar qué sensación es la más destacada durante el tiempo del consumo y sus resultados pueden relacionarse con la aceptabilidad, contribuyendo a una mejor comprensión de la elección y s respuestas de los consumidores (Varela *et al*, 2014). Tiene la ventaja de sumar el concepto de “temporalidad” que coincide con la dinámica de la masticación y de la transformación de la textura de los alimentos a medida que se mastican o trituran en la boca.

Experimentalmente, consiste en mostrar un listado consensuado de atributos en una pantalla de ordenador; los participantes según su percepción sensorial, después de poner en marcha el cronómetro seleccionarán a medida que trascurre el tiempo de ingesta y procesado oral el atributo que más les impacte en boca (Pineau *et al*., 2009). En el momento en que un nuevo atributo sea el predominante lo seleccionarán y habrá acabado el tiempo de predominio del atributo anterior; así actuará consecutivamente hasta terminar el tiempo de ingestión y que ya no se perciba ninguna sensación. En dicho instante se detendrá el cronómetro.

6.2.4. Aceptabilidad estática y dinámica

La percepción en boca es un proceso dinámico, ya que el alimento se va modificando a medida que se tritura e insaliva. El método de *Overall liking* permite dar en una sola estimación general de la aceptabilidad de un producto (una visión estática) mientras que el método *Dynamic liking* ofrece la alternativa de evaluar los cambios en la aceptabilidad que pueden surgir a lo largo del tiempo durante la ingestión. Galmarini *et al*. (2014) realizó un estudio comparativo de ambos métodos en gomas de mascar, obteniendo que ofrecen interesantes resultados y que la elección de una valoración estática o dinámica dependerá de las características del producto a evaluar y de los objetivos o necesidades del estudio.

Para efectuar las pruebas, se proporciona las muestras a los participantes que deben puntuar cuánto les gusta el alimento. En la modalidad estática esto lo hacen una única vez en una escala hedónica de nueve punto que va desde 1= “me disgusta mucho” a 9 = “me gusta mucho”. En la modalidad dinámica se ofrecen varias escalas (3 o 4) iguales y la puntuación la hacen en los diferentes estadios que se acuerden previamente (desde que se coloca el alimento a la boca hasta que se traga), dando lugar a la valoración múltiple que varía con el tiempo de procesado oral.

6.2.5. Escalas de adecuación “Just about right”

Las escalas JAR se utilizan en la ciencia del consumo y con frecuencia en los estudios de optimización de producto para identificar la valoración de los consumidores con respecto a ciertos atributos clave para la aceptabilidad del alimento en estudio. El análisis de las puntuaciones indican la dirección a seguir para un cambio en la formulación para mejorar un prototipo (Popper, 2014).

Se les proporciona a los participantes escalas de bipolares para cada uno de los atributos a evaluar, las puntuaciones van desde “demasiado poco” (límite inferior), pasan por un punto medio “está bien así” (que se relaciona con el “ideal” que el consumidor tiene en mente) y llegan hasta “demasiado”. El análisis de estos resultados con las herramientas estadísticas adecuadas determina qué atributos fueron los más importantes para mejorar la aceptación del producto.

6.2.6. Preguntas abiertas

Esta metodología se utiliza para conocer con mayor espontaneidad las características sensoriales, o de otra índole, que los participantes toman en cuenta para describir, comparar o categorizar diferentes muestras. El individuo no se encuentra sujeto a ninguna restricción al momento de responder a las preguntas por lo que se puede obtener información muy amplia y completa. Sin embargo; debido a la complejidad y gran número inherentes a los datos que se recopilan, el análisis cualitativo de las respuestas es a menudo difícil, laborioso y consume mucho tiempo (Varela y Ares, 2012). Por observación de los términos suele hacerse una categorización o agrupación de términos similares y analizar qué características asocian los consumidores con más frecuencia a un tipo de producto.

6.2.7. Mapas proyectivos

Este método deriva originariamente de la Psicología y fue previamente utilizado en estudios de mercadeo para obtener asociaciones entre productos.

Se presentan las muestras de forma conjunta, para que cada asesor individualmente las ubique en un espacio bidimensional (una hoja de papel blanco de tamaño grande), de acuerdo a las diferencias y similitudes que detecten entre ellas. De esta forma las muestras similares se ubicarán cerca entre sí y muestras diferentes se encontrarán distantes. Los criterios para dicho posicionamiento se escogen libremente por los consumidores. Por esta razón este método se considera un procedimiento flexible y espontáneo (Perrin *et al.*, 2008). El resultado de este procedimiento es un mapa global de las muestras y sus características.

En los mapas parciales, se solicita a los consumidores la ubicación de las muestras se haga según un criterio muy general pero fijo: por ejemplo que coloquen las muestras cerca o lejos teniendo en cuanta solamente la textura, o el sabor, etc. dependiendo de los intereses del estudio. De este modo, por comparación con el mapa global, se puede conocer la importancia relativa que el consumidor concede a cada factor.

7. SELECCIÓN Y CARACTERÍSTICAS DE UN ALIMENTO MODELO

Para la realización de la presente memoria no se llevaron a cabo estudios de intervención con humanos. El objetivo se centró en el área de la Tecnología de Alimentos: la aplicación de diversas estrategias para la reformulación de un alimento saciante.

El pastel de queso fresco es un postre lácteo refrigerado que se consume en España. Se compone básicamente de queso fresco, huevos, azúcar, leche, y almidón de maíz. Se diferencia de la tarta de queso tipo norteamericana (“cheese pie”) en que no posee una base crocante de bizcocho y tiene una textura suave, esponjosa y húmeda, de tipo gel aunque se puede cortar con un cuchillo y presenta un sabor lácteo suave.

La selección de este producto como base para la reformulación de alimentos saciantes de la presente memoria se fundamentó esencialmente en su base proteica y su bajo contenido en calorías. El queso fresco utilizado para la elaboración proviene de leche fresca de vaca pasteurizada. Su composición permite cambiar la proporción de los ingredientes minoritarios e incluir nuevos, realizando diferentes reformulaciones. Normalmente se buscó que las modificaciones de sus características no afectaran su aceptabilidad de forma importante. A pesar de contener azúcar y queso (éste es fresco con alto contenido en humedad y además puede utilizarse parcialmente desnatado) no presenta un contenido calórico alto (200 calorías como valor medio de un pastel entero de 100 g).

Existen algunos ejemplos de postres lácteos con capacidad saciante mejorada que ya están en el mercado, tales como algún tipo de yogur elaborados con un contenido proteico (mayor que el "normal" derivado de a leche fermentada) y suelen considerarse como un tentempié saludable. Sin

embargo, la literatura sobre el desarrollo de este tipo de alimento es aún escasa.
Debido a la dificultad para reformular alimentos que resulten más saciantes sin provocar cambios en su palatabilidad (y en consecuencia en su aceptabilidad), la tarea no es fácil.

La idea de obtener productos saciantes que adicionalmente se consideren como un postre agradable por parte de los consumidores, resulta un camino prometedor en el área de alimentos que contribuyan al control de peso y el tratamiento de la obesidad.

Por todo lo expuesto se han planteado una serie de objetivos que se enumeran en el siguiente apartado.

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OBJETIVOS

OBJETIVO GENERAL

Evaluar el efecto de diversos factores de composición, fisicoquímicos y sensoriales en pasteles de queso sobre las expectativas de su capacidad saciante y sobre el comportamiento gástrico *in vitro*

OBJETIVOS PARCIALES

- Estudiar el efecto de cada uno de los ingredientes minoritarios sobre la dinámica de la trayectoria oral y su relación con las expectativas de saciedad y aceptación.

- Analizar el efecto de la adición y concentración de proteína láctea o vegetal sobre las expectativas de saciedad.

- Estudiar el efecto de la complejidad en la apariencia y en la textura sobre las expectativas de saciedad.

- Evaluar el efecto de la adición y concentración de glucomanano de konjac sobre la viscosidad.en condiciones gástricas *in vitro*

- Valorar la importancia relativa de textura y sabor sobre las características sensoriales y no sensoriales y su relación con las expectativas de saciedad.

ESTRUCTURA DE LA TESIS DOCTORAL

El trabajo de investigación realizado ha dado origen a diversas publicaciones científicas, cuyo contenido se presenta en los distintos capítulos de la presente Tesis Doctoral. Las referencias de las publicaciones y el capítulo en que aparecen son:

Capítulo I

Marcano, J., Varela, P., Sanz, L., & Fiszman, S. (2015). Relating dynamic perception of reformulated cheese pies to consumers' expectation on satiating ability**.** *Enviado a: Food Research International*

Capítulo II

Marcano, J., Varela, P., & Fiszman, S. (2015). Relating the effects of protein type and content in increased-protein cheese pies to consumers' perception of satiating capacity". *Food & Function*, 6, 532-541

Capítulo III

Marcano, J., Morales, D., Vélez-Ruiz, J., Varela, P., & Fiszman, S. (2015). Does food complexity have a role in eliciting expectations of satiating capacity?. *Food Research International*, 75, 225-232.

Capítulo IV

Marcano, J., Hernando, I., & Fiszman, S. (2015).In vitro measurements of intragastric rheological properties and their relationships with the potential satiating capacity of cheese pies with konjac glucomannan. *Food Hydrocolloids*, 51, 16-22.

Capítulo V

Marcano, J., Ares, G., & Fiszman, S. (2015).Comparison of partial and global projective mapping with consumers: A case of study with satiating cheese pies. *Food Research International,* 67, 323-330.

En los capítulos I, II y III se evaluó la influencia de efectuar cambios en la formulación del alimento modelo sobre la capacidad saciante esperada y la percepción de complejidad de los consumidores. Estos objetivos se lograron realizando modificaciones en el contenido de los ingredientes minoritarios de la formulación (Capítulo I); incorporando proteína vegetal y láctea a diferentes concentraciones (Capítulo II) e incluyendo nuevos ingredientes con diferentes propiedades físicas y tamaño de partícula (Capítulo III).

En el capítulo IV se estudiaron los cambios reológicos producidos luego del proceso de digestión *in vitro* de pasteles de queso reformulados incorporando glucomanano de konjac a concentraciones crecientes, y su posible influencia sobre el efecto saciante.

Finalmente, en el Capítulo V se validó y comparó el uso de los mapas proyectivos global y parciales (textura y sabor) para caracterizar sensorialmente diferentes formulaciones de pasteles de queso y relacionar estos resultados con la capacidad saciante esperada por los consumidores.

CAPÍTULO I

Relating dynamic perception of reformulated cheese pies to consumers' expectation on satiating ability

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ABSTRACT

Designing satiating food is not an easy task. Food reformulation is normally done by altering the proportion of basic ingredients or by adding new minor ingredients. In general, the texture varies concomitantly with these changes, altering the way the food is processed orally and the complete eating experience. This highlights the interest of discovering how variations in minor ingredients influence texture and how this affects the dynamics of the oral trajectory. Six cheese pie formulations were prepared: basic recipe (B), no egg (B-E), no corn starch (B-CS) no sugar (B-S), added diary cream (B+C) and extra skimmed milk powder (B+M). Temporal dominance of sensations was used to show that the appearance and disappearance of each texture sensation experienced in the mouth during the eating process differed among the six pies, as did their relation to the consumers' expectation of satiating capacity scores and to the changes in composition. Two extreme behaviors were found: suppression of egg / addition of extra milk powder made the pies initially drier and harder, while suppression of corn starch / addition of cream gave the samples a soft, moist first impact. The former elicited higher expectations of satiating capacity. In addition, overall liking, liking evolving with time (dynamic liking) and the level of several key texture attributes' divergence from those of an "ideal" cheese pie were evaluated on bipolar just-about-right scales and through penalty analysis to gain insights into potential directions for reformulating acceptable pies.

Keywords: Dynamic perception, reformulation, satiating capacity, dynamic liking

1. INTRODUCTION

Tackling global obesity is unquestionably a goal of the utmost importance. Research targeting food reformulation for regulating hunger and satiety is one of the main diet-based approaches to the problem. The “satiety cascade” offers a number of points of reference for food reformulation and strategies can be planned in relation with the processes that start, sustain and terminate a meal, with processes that suppress further consumption, and with limiting over-consumption of calories or sustaining appropriate levels of intake (Mercer, 2013). At the pre-prandial and prandial stages, a number of subjective experiences take place at the cognitive and sensory levels. Both the quality (nutrient composition, flavor, texture and consumer appeal) and the quantity (oral metering, osmotic load, and gastric distension and emptying) of the food influence these experiences.

The importance of textural and structural properties in the perception of foods reformulated to enhance their satiating value has been widely demonstrated (Bolhuis, Lakemond, de Wijk, Luning, & Graaf C., 2011; Mars, Hogenkamp, Gosses, Stafleu, & De Graaf, 2009). Texture plays a role in satiation if it achieves a longer exposure of food to taste and the food energy is better sensed as a result, as a congruent association between sensory signals and metabolic consequences gives the human body sufficient cues for satiation (de Graaf & Kok, 2010).

Food is normally reformulated by adding new minor ingredients or by varying their basic proportion. In general, the texture varies with these changes, making it very difficult to reformulate food without altering the texture and eating experience. In consequence, it would be worth studying the contribution each minor ingredient change makes to texture perception. Since Hutchings and Lillford (1988) proposed the dynamic approach to characterize the perception of food texture, the concept of involving oral experience and time has been a significant development in texture studies, turning texture appreciation from a static process into a dynamic one (Chen, 2009). As the food piece undergoes a number of physical (and chemical) changes during mastication that turn a solid into a ready-to-swallow viscoelastic bolus, the temporal evolution of texture attributes could give relevant cues to the elicitation of satiating capacity signals. To the authors' knowledge, no information has been published about how dynamic texture perception – the sensations perceived throughout the complete chewing cycle – affects expectations of satiating capacity.

Studying the temporal aspects of perceptions during eating is a growing research topic in sensory science (Sudre, Pineau, Loret & Martin, 2012).Temporal dominance of sensation (TDS) enables several attributes to be assessed simultaneously and the sequence of dominant sensations of a product to be studied over a certain consumption time (Meyners 2011; Meyners & Pineau, 2010). TDS gives information about the temporality of the main food attributes (Meillon, Urbano, & Schlich, 2009, Ng, Lawlor, Chandra, Chaya, Hewson, & Hort, 2012). In some approaches the temporal aspects of hedonic assessment are also investigated.

In the present work, several formulations of a cheese pie made with fresh cheese, egg, maize starch, milk and sugar were investigated. One reason for choosing cheese pie was because its formulation is based on fresh cheese, and since protein is the most satiating macronutrient, a protein-based matrix (fresh cheese) would constitute a major advantage. In addition, the rest of the ingredients (minor components) make it possible to use a number of variations to obtain different textures that could play a role in eliciting different degrees of expected satiating capacity.

The aim of the present study was to discover how each individual minor ingredient of the cheese pie affects: a) dynamic texture perception, b) instrumental texture parameters, and c) dynamic liking, and to relate them to the expectations about satiating capacity elicited from consumers in order to pave the way for future food reformulation.

2. MATERIALS AND METHODS

2.1. Samples

Six different fresh-cheese pie formulations were designed (Table 1). Three samples were formulated by removing one of the minor ingredients from the basic recipe: no egg (B-E), no corn starch (B-CS) and no sugar (B-S). Two further samples were formulated by adding diary cream (B+C) or extra skimmed milk powder (B+M). The purpose of these removals and additions was to ascertain the contribution of each ingredient to the instrumental and sensory texture and how these variations could affect the perception of expected satiating capacity. None of the changes in the basic recipe (B) distorted the nature of the sample pies.

Table 1. Composition of the cheese pies

Ingredient (g/100g)	Sample					
	B	B-E	B-CS	B-S	B+M	B+C
Fresh cheese	55.0	68.7	57.9	61.1	50.6	34.1
Egg	20.0	0.0	21.1	22.2	18.4	12.4
Sucrose	10.0	12.5	10.5	0.00	9.2	6.2
Water	8.0	10.0	8.4	8.9	7.2	5.0
Skimmed milk powder	2.0	2.5	2.1	2.2	10.0	1.2
Corn starch	5.0	6.3	0.0	5.6	7.2	3.1
Dairy cream	0.0	0.0	0.0	0.0	0.0	38.0
Protein content (g/100g)	9.2	8.4	9.7	10.2	11.3	6.6
Fat content (g/100g)	9.8	9.7	10.4	10.9	9.1	17.5
Calories (cal/100g)	196.7	207.2	188.7	174.3	210.1	231.0

B: basic recipe; B-E, B-CS and B-S: basic recipe without egg, corn starch and sucrose; B+M and B+C: basic recipe with more milk and added dairy cream, respectively

2.2. Ingredients

The ingredients were full fat fresh cheese (starter-free, pasteurized, protein content 10.9 g/ 100 g, moisture 72 g/ 100 g and fat 14 g/ 100 g, as declared by the supplier, Hacendado, Spain), pasteurized liquid whole egg (Ovocity, Valencia, Spain), sucrose (Acor, Valladolid, Spain), maize starch (Maizena®, Barcelona, Spain), skimmed milk powder (Central Lechera Asturiana, Siero, Spain) and, only for sample B+C, dairy cream (fat content 30 g/ 100 g and moisture 65 g/ 100 g, as declared by the supplier, Hacendado, Spain).

2.3. Sample preparation

2.3.1. Batter preparation

The basic recipe batter was prepared in a mixer (Kenwood Major Classic, UK), at maximum speed (580 rpm). Firstly, the cheese was whisked for 1 min, then the egg and sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water and the starch dispersed in it. These were added to the mixture, which was beaten for a further 17 min. A total of 20 min processing was used for all formulations. For formulations B-E, B-CS and B-S, the corresponding missing ingredient was not added. In the case of samples B+M and B+C, the respective extra milk powder or cream was added after the starch dispersion.

2.3.2. Baking

The batter was poured into a heat-resistant silicone mold for five rounded pies (7 cm in diameter and 3.5 cm in height) and baked for 25 min at 180 °C in an electric oven (De Dietrich, Basingstoke, UK), preheated for 15 min. The oven and the tray position in the oven were identical in each case. The pies were left to cool at room temperature for 1 h, then demolded and stored under refrigeration (4 °C) for 24 h before the measurements and sensory tests were made. Each of the formulations was prepared in a similar way.

2.3. Instrumental texture measurement

Texture Profile Analysis (TPA) was performed at 10°C, considered the consumption temperature, using a TA.XT.Plus texture analyzer (Stable Micro Systems, Godalming, UK), with a flat probe (P/75). In the TPA, 4 cylindrical sub-samples (height 1.7 cm, diameter 2.2 cm) of each formulation, obtained from pies from different batches prepared on different days, were compressed to 40% of their initial height at 1 mm/s, with a 5 s resting time between the two compression cycles and a trigger force of 10 g. Their hardness (in N), springiness, cohesiveness, and chewiness (in N) were recorded using the Texture Expert software (version 6.0.6.0).

2.4. Sensory analysis

All the sensory tests were carried out in the sensory laboratories of the Institute of Agrochemistry and Food Technology (IATA-CSIC) and the Polytechnic University of Valencia, both of which are equipped with individual booths. In each sensory test, one piece of each sample (B, B-E, B-CS, B-S, B+M and B+C) was presented to the consumers at 10 ± 1 °C on small plastic plates labelled with random three-digit numbers in a sequential monadic series, following a complete block design balanced for carry-over position effects. The panelists were instructed to rinse their mouths with water after assessing each sample. No information about the ingredients of the cheese pies was given to the participants.

2.4.1. Temporal Dominance of Sensations (TDS)

In accordance with to the methodology used by Agudelo, Varela, & Fiszman (2015), three preliminary sessions were conducted to train a panel of sixteen assessors who had previous experience in sensory descriptive evaluations of dairy desserts (9 women and 7 men, aged between 20 and 44 years). In the first session, the panelists were introduced to the concept of the dominance of a sensation at a given time during the consumption of the food product and to the TDS technique, and had to list all the in-mouth sensations they felt while tasting all six samples, focusing on the changes in dominance over the other sensations during the consumption period. The descriptors were related to texture. In the second session, the most frequently mentioned attributes were selected and their definitions and the protocol for measuring them were developed until consensus was reached (Table 2). The eight attributes selected were soft, hard, moist, dry, grainy, creamy, fondant and covering. In the third session the panelists were able to understand the sequential attribute appearance concept, and participated in a simulated TDS session with several cheese cake samples in order to answer questions and get used to the computer program and methodology.

Subsequently, three formal TDS assessments of the six samples (Table 1) were performed three times on different days, resulting in three replicates for each sample. The panelists were instructed to put the whole sample in their mouth (always the same amount) and simultaneously start the software by clicking on the “start” button. Immediately, they showed which of the attributes on the list was dominant by clicking on that attribute on the screen. Each time the panelists felt a change in perception (either in intensity or in quality) and that a new attribute was dominant, they clicked the button corresponding to the new attribute. They knew that they did not have to use all the attributes in the list and were free to select an attribute several times, and they took into account that only one attribute could be selected at any one time. The evaluation continued until the panelists swallowed the sample completely and perceived no more sensations, at which point they clicked the “stop” button. The individual consumption time was calculated as the mean of the consumption time values for the three replicates of each sample, for each panelist. Data collection was performed using a computerized system: Fizz® (Biosystemes, Courtenon, France).

Table 2. Attribute and its definitions generated by the trained panel for the TDS task

Attribute	Description
Creamy	Homogeneous, soft, lubricated texture in the mouth
Soft	Requires little force for in-mouth processing
Hard	Requires great force for in-mouth processing
Dry	Absence of moisture
Moist	Perception of a humid, juicy sensation
Granny	Perception of particles
Fondant	The sample melts or disappears quickly in the mouth
Covering	Perception of a film covering the mouth organs which is difficult to remove

2.4.2. Expected satiating capacity and Dynamic liking

Another group of consumers (n = 93; 60 women and 30 men, aged between 20 and 64 years) rated the expected satiating capacity of the six cheese pies (Table 1) and their dynamic liking for them. on 9-point scales.
For the satiating capacity task, the anchors on the scale ranged from 1 = “If I ate the whole pie it would not fill me at all” to 9 = “If I ate the whole pie it would fill me a lot”. Since the cheese pies were cut into six wedge-shaped

pieces, the consumers could easily figure out the size of the whole cheese pie.

To assess dynamic liking, the consumers were presented with another set of samples. They rated their liking for each product 3 times over the mastication period of each sample, as follows:

- At the beginning of consumption (immediately after putting the cheese pie piece in the mouth),
- In the middle of the consumption time (self-assessed), and
- Just after swallowing.

For each sample, the consumers were presented with three 9-point hedonic scales for the three different times they had to award scores. The anchors on the scales ranged from 1 = “dislike extremely” to “9 = like extremely”, with a neutral intermediate category (5 = “neither like nor dislike”).

2.4.3. Overall liking and attribute adequacy using JAR scales

A new group of consumers (n=98, 66% women, aged between 18 and 64 years) evaluated their static overall liking for the six samples (on the same scale and with the same anchors as for dynamic liking). They then rated the consistency, moistness, pastiness, compactness and creaminess of the six samples on “just-about-right” (JAR) scales. The selection of attributes was partly based on those used for the TDS assessments, but unambiguous, easily-understood terms were chosen since the consumers were not trained. The JAR scales consist of five-point bipolar scales with end-points anchored with labels that represent the levels of the attribute that deviate in opposite directions from a respondent’s theoretical ideal or adequate level, while the central point is his or her ideal (Rothman, 2007). In the JAR test the consumers were asked “in your opinion this product should be ...", rated on the following scale: 1=much more…, 2=more…, 3=about right, 4=less…, 5=much less… (Lawless & Heymann, 1998).

2.5. Data analysis

For the TDS data analysis, the attribute chosen as dominant and the times when the dominance began and finished were collected for each panelist run. As the duration of the period up to complete swallowing with no more sensations perceived differed from one panelist to another, the data were normalized by adjusting them according to the individual duration of each panelist's consumption time (Albert, Salvador, Schlich & Fiszman, 2012). Finally, to build the TDS curves, the period when a sensation was dominant for a product at panel level (dominance rate) was computed at each point of time (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009). The data were collected with Fizz software version 2.45 (Biosystems, Counternon, France).

One-way analysis of variance (ANOVA) was applied to study the variability in individual consumption time from the TDS data, the overall liking and expected satiating capacity ratings for the samples, and the significance of the inter-sample differences ($\alpha = 0.05$). A two-way ANOVA was performed for the dynamic liking scores, taking the inter-sample and consumption time differences into account (Statgraphics Centurion 15, StatPoint Technologies, Inc. Warrenton, VA, USA).

The JAR results were analyzed by penalty analysis (PA) to identify potential directions for changes in the formulations. This technique relates JAR scales to liking data, especially in order to understand which side of the JAR scale is linked to lower hedonic ratings. The respondent percentages (X-axis) were plotted against the drop in liking (Y-axis) to gain an understanding of the attributes that most affected liking ratings (Plaehn

& Horne, 2008). In the PA, mean drops in overall liking of 1.0 or more, when mentioned by more than 20% of consumers, were considered a threshold for a meaningful decline in the liking of an attribute (Popper, 2014). Tukey's test was used to test the significance of the mean drops.

3. RESULTS AND DISCUSSIONS

3.1. Temporal dominance of sensations

Sample B (Figure 1a). The first significantly dominant sensation for sample B was *Soft*, which lasted for the first half of the consumption time. *Creamy* dominated the central time of consumption to a significant degree, with a higher dominance rate than *Soft*, while *Covering* appeared in the last part of the consumption time with the highest dominance rate of all (nearly 50%).

Sample B-S (Figure 1b). The temporal profile was not very different from sample B (with *Soft* and *Creamy* dominating the first and second thirds of the consumption time), although all the sensations for sample B-S showed lower dominance rate values than those for sample B. The role of sugar in the cheese cake batter is not only to increase its viscosity but also to stabilize the foam. According to Berry, Yang and Foegeding (2009), sucrose increased the interfacial elasticity of egg white proteins in an angel cake batter formulation, contributing better foam stability.

Sample B+M (Figure 1c). This sample presented a completely different temporal profile. *Hard* and *Dry* sensations showed significant high dominance rate values over the first two thirds of consumption time, while *Covering* appeared at significant levels after nearly 66% of the consumption time and lasted up to the end. It is worth noting that *Covering* was the last significantly dominant sensation in all the samples: it was found to be dominant from approximately 80-90% of the consumption time until the end, the only exception being the sample containing extra milk powder (B+M), in which it was dominant after 60% of the consumption time. This result was similar to that obtained in a study on temporal dominance of sensations in ice cream (Varela, Pintor & Fiszman, 2014), where the authors explained that after swallowing (with almost no ice cream left in the mouth) the panelists centered their attention on covering as it was probably the only remaining attribute, whatever the composition of the sample.

Sample B-E (Figure 1d). B-E displayed a similar profile to B+M, showing high (although lower than B+M) and significant *Hard* and *Dry* dominance rate values. Distinctively, *Grainy* dominated the temporal profile of sample B-E to a significant degree from 25% to 100% of the consumption time. The *Grainy* sensation sooner or later appeared in all the samples at a rate exceeding the significance level (except for sample B+C, where it only exceeded the chance level), indicating that it is a concomitant texture sensation for cheese pies. This is probably because consumers detected granules of cheese in the mouth (the cheese was whisked as the first step of cheese pie preparation). However, the high and prolonged dominance of a *Grainy* sensation exhibited by sample B-E would indicate that the absence of egg in the formulation increased the perception of these small granules. Eggs are used in foods, especially in baked goods batters, to impart several important techno-functional properties such as binding, tenderizing, texture stabilization, emulsification, and foaming, among others (Geera, Reiling, Hutchison, Rybak, Santha, & Ratnayake, 2011). During baking, egg coagulation as a result of heating is a crucial step in determining the final product texture (Kiosseoglou & Paraskevopoulou, 2014), as its gelling characteristics play a key role in batter structure control (Sozer, 2009).

Sample B-CS (Figure 1e). This sample showed a profile with an initial, significantly dominant *Moist* sensation with a very high dominance rate (nearly 47%), lasting over the first third of the consumption time. This could be because the starch acts as a water binding agent in the complete formulation, so when starch is present the available water is involved in swelling the starch granules and in their subsequent gelatinization during pie baking. Without the starch, more water probably become available and moisture-related sensations appeared. *Grainy* also presented a high and persistent dominance rate from 20% to the end of the consumption time, although with lower dominance values than B-E. *Soft* and *Creamy* shared the dominance with *Grainy* over the same period, but their rates were lower (although significant) during the middle of the consumption time. Samples B-E and B-CS presented the highest *Grainy* values, indicating that a lack of corn starch or egg in the formulation led to a less "cemented" pie mass with more individually-detectable cheese granules.

Sample B+C (Figure 1f). This sample shared significantly dominant *Moist*, *Soft* and *Creamy* values over the first third of the consumption time with sample B-CS. *Moist* appeared first, as for sample B-CS but with a much lower dominance value. They also shared the perception of a *Creamy* sensation, but in sample B+C it appeared earlier and lasted for longer. These three attributes could easily be associated with the presence of cream in the formulation. Sample B+C was the only one with a high dominance of *Fondant*, which lasted for the last two thirds of consumption time. None of the other samples showed any significant dominance of this attribute with the exception of B-S, where it had a brief significant dominance period. The *Soft, Creamy* and *Moist* attributes found initially in both B+C and B-CS could all be related to easy mastication and swallowing, while *Fondant* indicated that the sample readily disappeared in the mouth.

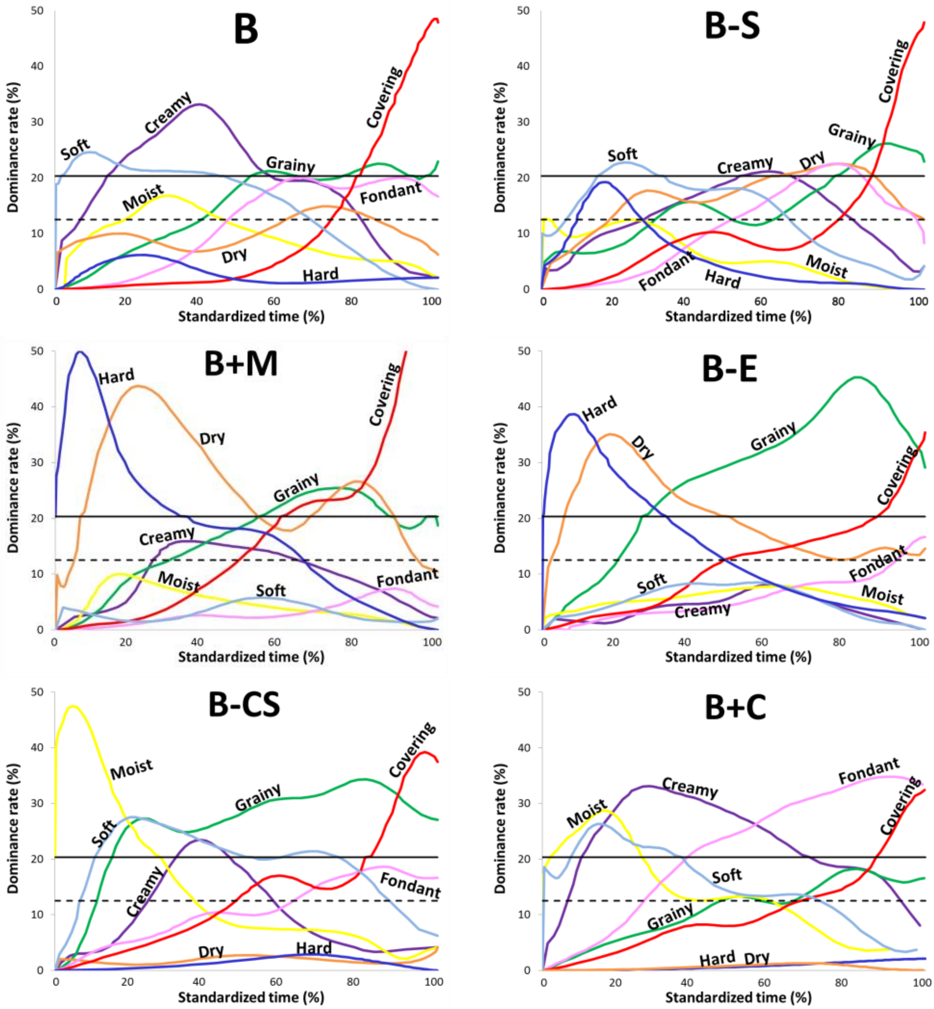

Figure 1. TDS curves per sample for the eight attributes: creamy, grainy, moist, dry, fondant, covering, soft, hard. Significance level (solid horizontal line), chance level (discontinuous horizontal line). B: basic recipe; B-E, B-CS and B-S: basic recipe without egg, corn starch and sucrose; B+M and B+C: basic recipe with extra milk powder and with added dairy cream, respectively

3.2. Relating TDS to expected satiating capacity

An analysis of the whole TDS scenario indicated that the cheese pie samples presented very different "first impacts" in the mouth: while B+M and B-E were perceived as hard and dry, B and B-S were soft and creamy and B-CS and B+C elicited an initial moist sensation. These results were in close agreement with the consumption time values for each sample, that is, the time the consumers took to complete the TDS task, calculated for each sample without time normalization across the panel (Table 3, mean value of the three repetitions): samples B+M and B-E took significantly longer to eat than B and B-S, while B+C and B-CS were significantly the quickest to be consumed. It seems logical that drier, harder samples took longer to process orally, whereas softer, moister and fondant ones took a shorter time.

Table 3. Mean values of Consumption time (in seconds, calculated from Temporal Dominance of Sensations data) and consumer scores for Expected satiating capacity, Overal liking, and Dynamic liking (three mastication periods) of the six cheese pie samples

Parameter	**Sample**					
	B	**B-E**	**B-CS**	**B-S**	**B+M**	**B+C**
Consumption time (s)	24.2^{b}	28.3^{c}	21.7^{ab}	24.6^{b}	28.8^{c}	20.5^{a}
Expected satiating capacity	6.2^{b}	6.8^{c}	5.5^{a}	6.4^{b}	7.1^{c}	5.3^{a}
Dynamic liking						
Initial	$5.8^{A,b}$	$4.7^{A,a}$	$4.9^{A,a}$	$5.4^{A, ab}$	$5.8^{A,b}$	$4.5^{A,a}$
Middle	$6.3^{B,b}$	$5.1^{B,a}$	$5.3^{B,a}$	$5.8^{B,ab}$	$6.2^{B,b}$	$5.0^{B,a}$
Final	$6.4^{B,b}$	$5.4^{B,a}$	$5.7^{B,a}$	$5.8^{B,ab}$	$6.3^{B,b}$	$5.3^{B,a}$
Overall(static)liking	5.9^{c}	4.9^{a}	4.7^{a}	$5.6^{b,c}$	5.9^{c}	4.6^{a}

B: basic recipe; B-E, B-CS and B-S: basic recipe without egg, corn starch and sucrose; B+M and B+C: basic recipe added with more milk and dairy cream, respectively. ^{a,b} Different superscript low case letters within the same row denote significant differences ($p<0.05$). ^{A,B} Different superscript bold letters within the same column for dynamic liking scores denote significant differences ($p<0.05$)

These results were also completely in line with the instrumental TPA measurements (Table 4): the hardness values were ordered B+M > B-E > B > B-S > B-CS > B+C at significant intervals, while the chewiness values followed the same order but the differences were only significant for a few of the consecutive samples.

Table 4. Mean values (n=3) and standard deviation for the instrumental texture profile analysis (TPA) parameters (hardness, springiness, cohesiveness and chewiness) for the six cheese pie samples

Sample	TPA Parameters			
	Hardness(N)	**Springiness**	**Cohesiveness**	**Chewiness(N)**
B	3.62[d] (0.60)	0.58[a] (0.08)	0.38[a] (0.03)	0.83[b] (0.29)
B-E	5.62[e] (0.28)	0.73[b] (0.05)	0.48[b] (0.03)	1.96[c] (0.22)
B-CS	2.18[b] (0.34)	0.61[a] (0.12)	0.35[a] (0.04)	0.51[a] (0.58)
B-S	2.89[c] (0.40)	0.62[a] (0.11)	0.37[a] (0.05)	0.69[ab] (0.25)
B+M	7.16[f] (0.65)	0.64[a] (0.05)	0.45[b] (0.07)	2.01[c] (0.41)
B+C	1.42[a] (0.30)	0.76[b] (0.06)	0.45[b] (0.03)	0.49[a] (0.20)

[a,b] 'Different superscript letters in the same column denote statistically significant differences ($p<0.05$)
Values between parentheses are standard deviations

The expected satiating capacity scores (Table 3) also followed this order. Samples B+M and B-E, the hardest and driest pies on “first impact”, elicited the highest expectations of satiating ability. In addition, they also seemed to be more laborious to chew (longer consumption times), so they would generate longer oro-sensory exposures. At the other extreme, samples B+C and B-CS, with first-impact sensations of moist, creamy and soft, elicited the lowest expected satiating capabilities, and correspondingly were consumed the quickest (Table 3).

3.3 Dynamic and static liking scoring

Liking is an important factor to take into account when designing a novel food category such as enhanced-satiation products. For many products, measuring liking is still mainly accomplished through a single integrated overall liking response (Sudre, Pineau, Loret, & Martin, 2012). However, as stated above, the temporal dimension of the perception of texture (and flavor) is very relevant and the texture perceived in the mouth largely depends on the behavior of the food piece when it is broken down and physically transformed by the organs of the mouth (teeth, tongue, palate, etc.) and the saliva during mastication (Bourne, 2004; Foster, Grigor, Cheong, Yoo, Bronlund, & Morgenstern, 2011). In the mouth, cheese pies are comminuted into finer and finer particles, mixed with saliva, brought to body temperature and completely transformed into a semisolid, viscoelastic bolus mass that is finally ready to be swallowed. Cheese pies that are initially drier and harder require different oral processing to those that are softer and moister. All these characteristics and physical (and chemical) transformations are continuously sensed in the mouth during the consumption time, leading to different hedonic appraisals. The final balance among all the appraisals leads to the global liking sensation. However, initial and intermediate states of the bolus can generate evolutionary liking sensations that can influence both liking and satiating expectations.

In the present study, both approaches were adopted: dynamic liking (during the consumption of each sample, rated at three moments of the consumption time) and static liking (single scores).

The dynamic liking results (Table 3) showed that the consumers were able to perform the task of scoring the evolution of their liking for a cheese pie during its consumption. At panel level, the results of the ANOVA for the 3-step liking method showed a significant increase in liking over time for all the samples ($p < 0.05$). The ‘‘time x product’’ interaction was not significant ($p < 0.05$), meaning that the evolution of liking over time did not differ among them. Moreover, the dynamic approach showed that liking scores increased over the different stages of pie consumption, although no statistically significant differences were found between the values for the second and third evaluation times. Samples B and B+M were significantly the most liked at first bite, whereas no significant differences were found between the rest of the samples. The same pattern was found for the second and third scoring times.

The mean static liking scores were similar to those for the first rating time in the dynamic evaluation. Sudre *et al.* (2012), working with breakfast cereals, found that for a majority of subjects the overall liking score referred rather to a first impression about the product at the beginning of mastication than to subsequent perceptions.

In terms of product differences, the overall liking approach led to similar conclusions to those of the dynamic liking scores: B+M and B were the best-liked pies and B-CS and B+C the least-liked.

TDS curves may help to understand the reasons for the low liking scores for samples B-CS and B+C. These were the only ones with moist as the earliest perception, followed by soft: this first impact in the mouth of what were probably unexpected sensations for a cheese pie could have lowered their liking scores. On the other hand, the best-liked samples, B and B+M; showed very different first-impact sensations to each other, as B was soft and creamy whereas B+M was hard and dry. From their liking scores it was evident that these sensations were all liked, probably because they moved within an acceptable range of consistencies that was expected by or familiar to consumers. Largely unexpected texture features found in a product might be perceived by consumers as an undesired sensory property, or even as indicating a defective product, since the product does not match the expectations (Dar & Light, 2014).

3.4. Optimal attribute levels and their relation to liking, measured by Penalty Analysis

Penalty analysis (PA) helps to identify the distance from the optimal level of certain attributes in a given sample, signaling the direction to go in order to get closer to the “ideal” and so increase the overall liking for the product. As it is an attribute-by-attribute analysis, several potential product improvements can be selected by identifying the attributes in the upper right-hand corner of the PA plots (Popper, 2014). The analysis aims to identify to what degree the products fails to deliver its optimum, and to gain a better understanding of the attributes that most affect the liking ratings (Plaehn & Horne, 2008). In the present study, an attribute was considered penalizing when the respondent percentage was higher than 20% (Xiong & Meullenet, 2006) and the drop in overall liking was higher than 1. An attribute in the upper right-hand corner of the PA plot meant that a high number of consumers had said the attribute level was not right, with a big impact on overall liking.

In general the drops in linking were not very penalizing, with values generally not exceeding 2 points. PA of the JAR data (Figure 2) showed that a lack of creaminess was penalizing in samples B-S, B+M, B-E and B-CS. Creaminess is an attribute that is generally considered positive in dairy desserts, since it is much appreciated. In general, creaminess is an index of the richness of the ingredients, and involves a number of factors associated not only with texture but also with flavor (particularly vanilla, sweetness and fat-related flavors) or pleasantness (Antmann, Ares, Salvador, Varela, & Fiszman, 2011). Several authors advise about the bias that asking consumers about attributes that have a positive halo may entail (Popper, 2014), since it would seem logical for them always to have a tendency to rate the attribute (creaminess in the present case) as “not enough”. However, sample B+C was found significantly “too creamy” by almost 30% of consumers, with a penalizing drop in liking of 1.0 point. This sample was also penalized for being “too moist” (marked by more than 70% of consumers, with a drop in liking of 1.8), indicating a further way in which this sample diverged from the ideal. Sample B+C had a dynamic profile that described a moist, soft, creamy and fondant texture, probably distancing it from the familiar, expected texture for a cheese pie, which normally lasts longer in the mouth.

“Too compact” and “too consistent” were the penalizing attributes for samples B+M and B-E, which also showed hard and dry first sensations in their TDS dynamic profiles and the highest hardness values in the instrumental TPA.

Finally, “too pasty” was penalizing for samples B and B-CS. These, along with sample B+C (in which pastiness was penalizing but not significantly so), had the same first impact of a soft, creamy and moist dynamic sensation profile. Probably, the oral processing strategy for these kinds of sample was different from the rest. The very first sensing of a sample’s texture prior to the beginning of oral processing determines whether squeezing rather than chewing will be selected. Yokoyama *et al.* (2014) stated that in squeezing, the tongue performs the size reduction work, modulating both the magnitude and duration of tongue pressure over a wide area of hard palate, depending on the consistency of the sample. In this situation, the formation of a squeezed paste between tongue and palate would be the first step in oral processing that could lead to a perception of pastiness. In fact, these samples scored the least for expected satiating capacity (Table 3).

According to the PA, the most balanced sample was sample B, which had drop-in-liking values not exceeding 1.6, with too pasty as the only significantly penalizing attribute.

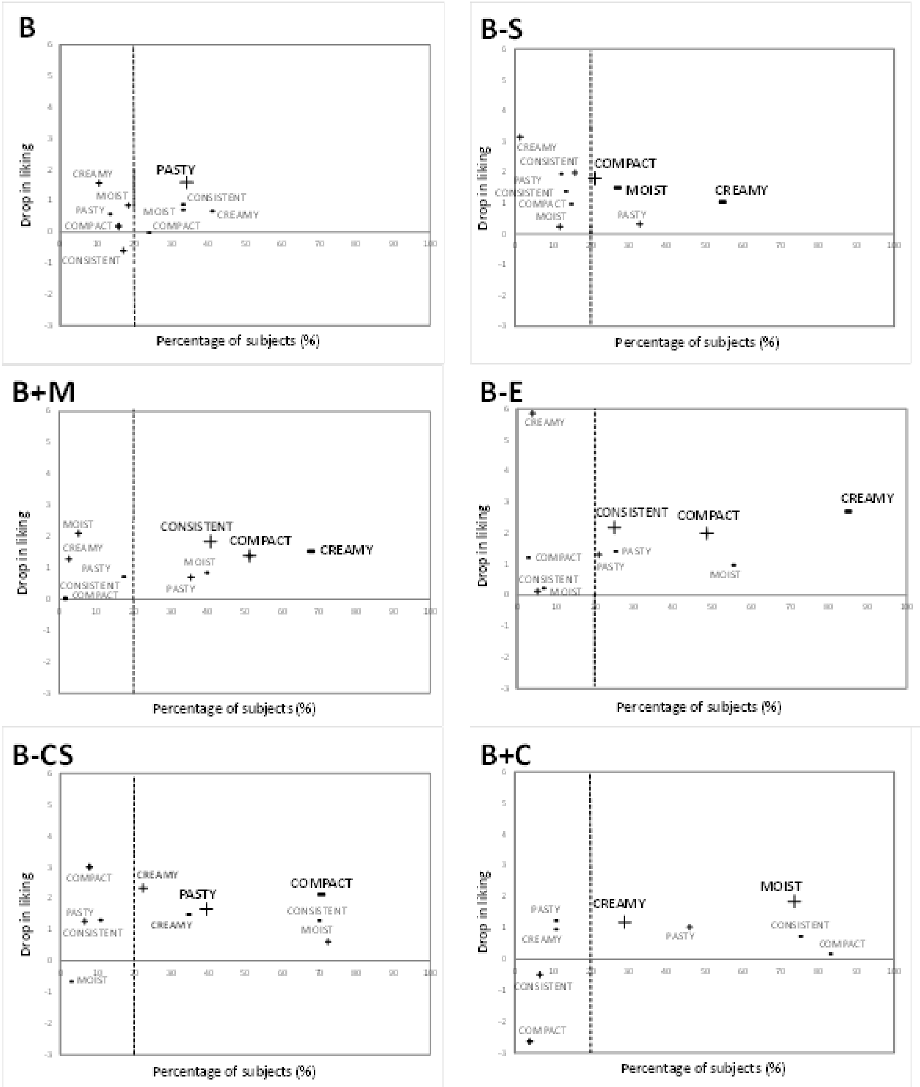

Figure 2. Penalty analysis of the six cheese pie samples. Representation of mean drops in liking vs. percentage of consumers. The cut-off point was 20% of consumers stating that an attribute was "not enough" (-) or "too much" (+). Attributes in large bold print are significantly penalising

4. CONCLUSIONS

Designing satiating food is not an easy task. Reformulating new recipes for this purpose brings into play a number of interrelated factors affecting texture and mouthfeel. In the present study an apparently simple experiment was performed: introducing only minor alterations in some of the ingredients in the basic cheese pie recipe. Dynamic sensory techniques showed that the first impact in the mouth delivered much of the estimated satiating level of the samples, since those sensations correlated well with the samples' expected satiating capacity scores.

The liking results, both dynamic and static, combined with a penalty analysis of some key attributes (which indicated the divergence from their ideal level for consumers), contributed to a knowledge of how the range for a texture can move without causing disappointing hedonic results. These results also showed the directions to take to improve the food product eating experience: small texture changes can enhance the sensory experience and can be used to guide the consumer towards associations with enhanced satiating capacity, as in the present case.

Finally, an interesting idea emerged: did the samples require different oral processing strategies? What is the difference in perception if the sample texture changes from requiring true mastication to requiring only squeezing? Further studies are needed to discover the importance of these different oral strategies for eliciting satiating capacity expectations about semi-solid foods.

ACKNOWLEDGEMENTS

The authors are grateful to the Spanish Ministry of Economy and Competitiveness for financial support (AGL2012-36753-C02-01). They would also like to thank Mary Georgina Hardinge for assistance in correcting the English manuscript.

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CAPÍTULO II

Relating the effects of protein type and content in increased-protein cheese pies to consumers' perception of satiating capacity

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Food & Function, 6 (2015), 532-541

ABSTRACT

Since protein has been shown to have the highest satiating-inducing effects of all the macronutrients, increasing the protein level is one of the main strategies for designing food with enhanced satiating capacity. However, few studies analyze the effect that protein addition has on the texture and flavor characteristics of the target food item to relate them to the expected satiating capacity it elicits. The present work studied cheese pies with three levels of soy and whey proteins. Since the protein level altered the rheological behavior of the batters before baking and the texture of the baked pies, the feasibility of adding several protein levels for obtaining a range of final products was investigated. A Check-all-that-apply question containing 32 sensory and non-sensory characteristics of the samples were performed with consumers (n=131) who also scored the perceived samples' satiating capacity. The results showed that the type and content of protein contributed distinctive sensory characteristics to the samples that could be related to their satiating capacity perception. Harder and drier samples (high protein levels) were perceived as more satiating with less perceptible sweet and milky cheese pie characteristic flavors Soy contributed off-flavour. These results will contribute a better understanding of the interrelation of all these factors, aiding the development of highly palatable solid foods with enhanced satiating capacities.

1. INTRODUCTION

The high prevalence of obesity in the industrialized world is partly due to the available food supply;[1] nowadays, the obesogenic environment, among other factors, triggers opportunities to unhealthy snacking in the western world, particularly among adolescents.[2] A useful approach for helping people to manage their appetite and food intake over the short term would be designing healthy everyday food products with enhanced satiating properties.[3] Three interrelated routes for food satiating enhancement.[4] The first route is to change the food composition to develop stronger physiological satiation and satiety signals, being satiety the process that causes one to stop eating, and satiation the feeling of fullness that persists after eating suppressing further food intake until hunger returns. The second route is to anticipate and build on smart external stimuli at the moment of purchase and consumption. Finally, the third route is to improve the palatability and acceptance of satiating capacity-enhanced foods. Based on these statements the present study will attempt the development of healthy snacks with enhanced satiating capacity.

The well-known satiating effect induced by protein-enriched meals in animals and humans has long been used in diets to decrease their sensation of hunger and lose weight.[5] In consequence increasing the amount of protein to reformulate a dairy protein-based food product was considered an interesting starting point in the present study. Proteins are widely cited in the literature as the macronutrient with the most potent satiety-inducing effect. The effects of high or normal casein-, soy-, or whey-protein breakfasts on specific hormones, amino acid responses and subsequent energy intake have been compared and found to be dose-dependent.[6] For example, gastrointestinally-digested 7S fraction of soy protein has significant CCK1R activity.[7] Contradictory results were obtained by other authors[8] varying the protein source in a mixed meal did not affect food behavior in healthy humans, probably because coingestion of carbohydrate and fat with protein buffers the kinetics of the physiological mechanisms involved in postprandial satiety after a protein load. Proteins from different sources can be added to food formulations to increase their protein content, and hence their satiating capacity; for this reason, two kinds of proteins: milk whey and soy, the most widely used in the industry, were selected for the present study. Increasing the amount of proteins will raise, in turn, the nutritional value of the final product. The latest research showed that protein quality evaluation in human nutrition should take into account their digestible amino acid contents, with each amino acid being treated as an individual nutrient; and the protein digestibility, considering the digestibility of the indispensable amino acids. Soy protein concentrate (SPC), compared with other vegetable sources, has good digestibility; however, differences in amino acid ileal digestibility were found between milk and soy for several amino acids as well as overall nitrogen digestibility, with the milk values being higher in all cases.

Whey protein isolated (WPI) consists mainly of β-lactoglobulin, α-lactalbumin, bovine serum albumin, immunoglobulins and lactoferrin[9] and glycomacropeptide corresponding to amino acid residues 106-169 from κ-casein. This macropeptide is released into the whey during the renneting of milk and is concentrated together with the whey proteins during the ultrafiltration of rennet whey.

In general, whey protein isolate (WPI) forms better heat-induced gels than whey protein concentrates and has better functional properties, which could be explained by the differences in composition, particularly a higher β-lactoglobulin content and lower fat, lactose and phospholipid contents, and by the extent of denaturation and protein aggregation. The low glycomacropeptide, non-protein-nitrogen and proteose peptone contents in

WPI may also partly explain the superior gelation properties of these protein products.[10]

Soy protein concentrate (SPC) has a good aminoacid balance and is particularly rich in lysine. Soy proteins show health-promoting effects associated with reduced risk of cardiovascular disease, breast, prostate and colon cancers and bone health improvement.[11] SPC is typically prepared from milled soy-bean white flakes or flours by solubilizing the protein at pH 6.8–8 and 27–66ºC, using aqueous alkaline agents, followed by acidifying to pH 4.5 and concentrating the resulting curd by centrifugation after adjustment to pH 6.5–7.0 or by spray-drying the acidic form.[12]

Among other properties, as their gelling capacity, the water holding capacity (WHC) of proteins could perform an important role in the physical (e.g., elasticity, swelling), chemical (e.g., emulsification) and sensory (e.g., juiciness) attributes of food; in a comparison study among several proteins, soy protein had the highest WHC values, followed by whey protein[13]. Changes in rheology and texture could in turn affect the expected satiating capacity of protein-added products in terms of in-mouth residence time and the distinctive oral processing required. Therefore the effects of several contents of these two proteins on the batter rheology and final instrumental texture of the model food selected will be compared in the present study to check the feasibility of obtaining appropriate final products.

The importance of in-mouth cues, such as food texture, has been shown to play a role in eliciting satiating effects. In working with flavored milk drinks it was shown[14] that small changes in the sensory characteristics – thicker, creamier – changed the degree to which the beverages were perceived as being more satiating, that said, when predicted by relevant sensory cues. For this reason, when increasing protein contents to design foods with high satiating capacity, it is important to bear in mind that they bring about not only physical but sensory changes in the matrix of the reformulated food. This can influence how the consumers perceive the characteristics they associate with satiating capacity and thus change in their hedonic response.

Frankfurter-style sausages with double the protein of the normal formulation were perceived as more satiating during the first 90 min after the first meal and as less juicy, adhesive, harder and more granular than ones that contained less protein.[15] Astringency and the appearance of unpleasant notes such as “animal” or “musty” have been reported in high-protein satiating beverages formulated with whey proteins.[16] Some studies have suggested that proteins may be differentiated in terms of their satiating capacities. In the present study both distinctive sensory properties and expected satiating capacity provided by each protein to the model food will be evaluated.

A few examples of milk-based desserts with enhanced satiating capacity are already on the market, such as yogurts prepared with higher protein content than “normal”, and they are considered as a healthy snack. However, literature on the development of real food items with enhanced satiating capacity is still scarce. The fresh cheese pie selected as the model in the present study is a refrigerated dairy dessert that is basically made of fresh cheese, eggs, sugar, milk, and starch. It differs from American cheesecake in not having a crust and having a soft, spongy, moist, gel-like texture which can be cut with a knife. Fresh cheese is made from pasteurized non-cultured cows’ milk and is characterized by a creamy, firm texture with a mild milky flavor. This dessert therefore presents a good option for increasing the protein content with the objective of enhancing its satiating effect, although changes in the texture and flavor of the final product may be expected, as well as changes in the rheology of the batter before baking.

The present study aims to evaluate the effect of adding increasing amounts of whey protein isolate (WPI) and soy protein concentrate (SPC) on the perception of enhanced satiating capacity of reformulated cheese pies.

The rheology of the batters before baking and the instrumental texture of the baked pies with different protein source and contents were investigated to obtain a range of pies without distorting the essence of the products. To know the distinctive characteristics that both proteins and their levels confer to the pies and which of them are more related to consumers' perception of satiating capacity a Check All That Apply question was performed.

2. MATERIAL AND METHODS

2.1. Ingredients

Eight pie samples were formulated (Table 1). The ingredients were: full-fat fresh cheese (starter-free, pasteurized, protein content 10.9 g/100g, moisture 72 g/100g and fat 14 g/100g as declared by the supplier, Hacendado, Spain), low-fat fresh cheese (protein 12.3 g/100g, moisture 83 g/100g and fat content 0.2 g/100g, Hacendado, Spain), pasteurized liquid whole egg (Ovocity, Valencia, Spain), sucrose (Acor, Valladolid, Spain), maize starch (Maizena®, Barcelona, Spain), skimmed milk powder (Central Lechera Asturiana, Siero, Spain), whey protein isolate (WPI, Best Protein®, 90 g/100g protein content, Barcelona, Spain) and soy protein concentrate (SPC, protein content 69 g/100 g, Solcon IP Brenntag Quimica, Massalfassar, Spain).

Table 1. Composition of the cheese pie samples[a]

Ingredient (g)	Sample							
	CFF	**CLF**	**W1**	**W2**	**W3**	**S1**	**S2**	**S3**
Fresh cheese	55.00	27.50	26.95	26.67	26.40	16.17	16.00	15.84
Low-fat cheese	0	27.50	26.95	26.67	26.40	37.73	37.35	36.96
Whole egg	20.00	20.00	19.60	19.40	19.20	19.60	19.40	19.20
Sucrose	10.00	10.00	9.80	9.70	9.60	9.80	9.70	9.60
Water	8.00	8.00	7.84	7.76	7.68	7.84	7.76	7.68
Maize starch	5.00	5.00	4.90	4.85	4.80	4.90	4.85	4.80
Skim. milk powd.	2.00	2.00	1.96	1.94	1.92	1.96	1.94	1.92
WPI	0	0	2.00	3.00	4.00	0	0	0
SPC	0	0	0	0	0	2.00	3.00	4.00
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total protein cont.	9.2	9.6	11.2	12	12.8	10.9	11.5	12.1
Total fat content	9.8	6	5.9	5.9	5.8	4.5	4.4	4.4

[a] CFF: control full-fat; CLF:control low-fat; W1, W2 and W3: added whey protein (2, 3 and 4 g per 100g respectively); S1, S2 and S3: added soy protein (2, 3 and 4 g per 100g respectively)

Two control samples were prepared: one was prepared with full-fat cheese (the full-fat control or CFF) and another was prepared with 50:50 full-fat:low-fat cheese (the low-fat control or CLF), since the pie with total replacement by low-fat cheesecollapsed after baking. In the present study, maximum replacement of the full-fat cheese by low-fat cheese was sought, since the health concerns associated with fat consumption have led to an increase in the demand for low-fat dairy products, especially when designing foods with enhanced satiating capacity. Preliminary tests were run to obtain samples containing added WPI and SPC with the minimum amount of full-fat cheese in their composition. Bearing this in mind, samples W1, W2 and W3 were formulated with increasing amounts of whey protein isolate (WPI) and 50:50 ratio of full-fat:low-fat fresh cheese, while samples S1, S2 and S3 were formulated with increasing amounts of soy protein concentrate (SPC) and a 30:70 ratio of full-fat:low-fat fresh cheese (Table 1), since soy protein conferred better viscosity/foaming properties on the batter than whey proteins. In this study, irrespective of the protein content added, the proportions of the other ingredients (cheese/egg/sugar, water/milk powder and starch) remained the same as in the control sample.

2.2. Sample preparation

2.2.1. Batter preparation

The batter was prepared in a mixer (Kenwood Major Classic, UK), at top speed (580 rpm). Firstly, the cheese was whisked for 1 min, then the egg and sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water and the starch dispersed in it. These were added to the mixture, which was beaten for a further 1 min. Lastly, when necessary, the protein was added and the final mixture was beaten for 16 min. A total of 20 min processing was used for all formulations.

2.2.2. Baking

The batter was poured into a heat-resistant silicone mold for five rounded pies of 7 cm in diameter and 3.5 cm in height, and baked for 25 min at 180ºC in an electric oven (De Dietrich, Basingstoke, UK), preheated for 15 min. The oven, the tray and the tray position in the oven were identical in each case. The pies were left to cool at room temperature for 1 h, then demolded and stored in refrigeration (4 ºC) for 24 h before the measurements were made.

2.3. Small-strain rheological measurements of the batters

A controlled stress rheometer (AR-G2, TA-Instruments, Crawley, UK) was used. The strain applied was selected to guarantee the existence of linear viscoelastic response according to preliminary stress sweeps performed in all samples. The batters were all kept at 25ºC for 30 min after batter preparation before performing the rheological tests. The samples were allowed to rest in the measurement cell for a 5 min equilibration time. A 40-mm diameter plate-plate sensor geometry with a serrated surface and a 1 mm gap was employed. Vaseline oil was applied to the exposed surfaces of the samples to prevent sample drying during testing.

To simulate the effect of baking on the pie batter, temperature sweeps were performed from 25ºC to 80ºC at a heating rate of 1 ºC/min. Preliminary stress sweeps were carried out at 25ºC and at 80ºC to select strain values that would guarantee the existence of linear viscoelastic response. The temperature sweep was stopped at the corresponding temperature and after a 10 min temperature-equilibration time, the stress sweep was performed at 1Hz. In addition, mechanical spectra in the linear region from 10 to 0.01 Hz at 25 ºC and at 80 ºC (after the equilibration time and temperature sweep) were also recorded in separate tests. The storage modulus (G') and the loss modulus (G'') were recorded. Each formulation was measured twice from different batches. The data were recorded over time, using the TA data analysis software provided by the instrument's manufacturer.

2.4. Baked cheese pie instrumental texture measurements

The instrumental texture measurements were made with a TA.XT.plus Texture Analyser (Stable Microsystems, Godalming, UK). Each formulation was prepared twice, on different days. Three cylindrical pieces were cut from each baked pie with a round biscuit cutter. The top and bottom of each cylinder were discarded, leaving cylindrical pieces 22 mm in diameter and 17 mm in height. A double compression test (texture profile analysis, TPA) was performed at 8ºC with a flat-ended cylindrical probe (P/75), to reach 40% compression (6.8 mm of probe traveling distance) at a speed of 1 mm/s, with a 5 s waiting time between the two cycles. The parameters obtained from the curves were hardness (in N), springiness, cohesiveness, chewiness (in N) and resilience, using the Texture Expert software (version 6,0,6,0).

2.5. Consumer tests

Six samples were evaluated: CFF, CLF, W1, W3, S1, and S3 (Table 1). Samples with intermediate protein content (W2 and S2) were not evaluated to avoid consumers' fatigue, especially since the "sensation of fullness" will be scored.

All experiments were performed in compliance with the national legislation, and according to the institutional framework and practices established by CSIC Ethics Committee.

2.5.1. Check-all-that-apply (CATA) questionnaire

The CATA question, in which consumers describe a product by selecting appropriate words from a given list, has the advantage of obtaining direct consumer feedback, which is essential for reformulating existing products, among other applications.[17] Consumers (n=131) were recruited based on their consumption of the target product, as well as their interest and availability to participate; 65% were female, with ages ranging between 18 and 60 years. The test was performed in tasting rooms at the Institute of Agrochemistry and Food Technology (IATA-CSIC) and the Polytechnic University of Valencia. The consumer sample comprised varying household compositions, income levels, education levels, etc. but was not representative of general population in Valencia, Spain.

In the present study, 32 terms were selected from the available literature on sensory attributes of dairy desserts and on products with soy and whey protein added, and from informal tasting by researchers and a sensory descriptive panel. Some of these terms related to product use and satiating capacity-related sensations were also elicited for each pie. The instruction given to the participants was: "Please check all the answers that apply to the cheese pie you are tasting". Two groups of terms were included in the CATA question: sensory and non-sensory terms. The first group was composed of the following 28 sensory attributes: Hard, Spongy, Soy taste, Compact, Grainy, Moist, Cheese taste, Light texture, Floury taste, Sticky, Off-flavor, Fondant, Sandy, Tender, Dense, Gummy, Caramel taste, Creamy texture, Smooth, Sweet, Astringent, Earthy taste, Soft, Milky taste, Pasty, Dry, Porous texture, Starchy taste. The second group of 4 terms were usage and satiating capacity-related terms: "If I eat the whole pie I will not be hungry for a long time", that indicated high satiating capacity, "Even if I eat the whole pie I will be hungry shortly" that indicated low satiating capacity, "I would eat it as a snack" and "I would eat it as a dessert". These terms were randomized within the two groups between products and across consumers. The test was recorded on paper and self-completed after instructions were given.

The pies were cut into eight wedge shaped pieces; the samples were assessed in a standardised tasting room equipped with individual booths.[18] Each consumer received the six samples of cheese pie in a sequential monadic series in a single session, following a balanced complete block experimental design (William's design); he/ she was asked to indicate the CATA terms that applied to the samples which were described as "cheese pie samples". Each sample was served in a small plastic tray coded with three digit random numbers; they were served at 10ºC. Still mineral water was available to rinse the mouth between samples; consumers were asked to rest for 30 seconds between samples.

2.5.2. Expected satiating capacity evaluation

Academia distinguishes between satiation and satiety; however, normal consumers are not aware of such difference.[19] In the present study after tasting the samples the consumers had to score their expectation on how filling each cheese pie is likely to be. In this scenario both concepts – satiety and satiation – are probably blurred. This reason is why the term “expected satiating capacity” was used in the results’ discussion.

After completing the CATA question the consumers scored the expected satiating capacity of each cheese pie sample on a nine-point scale, from 1=”If I ate this whole pie it would not fill me at all ” to 9=”If I ate this whole pie it would fill me a lot”. As the cheese pies were cut in eight wedge-shape pieces, the consumers could easily imagine the size of the whole cheese pie.

2.6. Data analysis

All the instrumental tests were carried out in duplicate with samples prepared on different days. Analyses of variance (ANOVA) were performed to compare the effect of adding the different proteins on the rheological and texture parameters of the cheese pie samples. When a significant difference ($p<0.05$) was detected in some variable, Tukey's means test was applied ($\alpha = 0.05$). The statistical analyses were performed with Statgraphics Centurion XVI (Warrenton, Virginia, USA).

The CATA results were analyzed for significant differences using non parametric tests. A chi square test was used to study the global differences between cheese pie samples in the CATA responses. Cochran's Q test[20] was performed to identify significant differences between samples for each of the terms included in the CATA question. For each cheese pie, the frequency of use of each sensory or usage attribute was determined by counting the number of consumers that selected that term to describe the corresponding sample.

A multiple factor analysis (MFA) was run on the CATA frequency counts of the significant attributes to understand the comparative positioning in sample and attribute two-dimensional plots as perceived by the consumers. Variables for the MFA were grouped as: taste, texture & non-sensory, with the intention to weight any possible effect, such as the final perceptual map is not dominated by only a few attributes.[21] Satiating capacity was used as a supplementary variable in the CATA data analysis to better understand its relation to the perceptual space. The statistical analyses were performed with XLStat 2010 software (Addinsoft, Paris, France).

3. RESULTS AND DISCUSSION

The aim of the present study was not to discover or fully characterize the structures that govern the mechanical behavior of the selected food systems, but to investigate the feasibility of obtaining a range of suitable cheese pies with increased amounts of proteins; for this reason the rheological behavior of the batters, their performance during baking and the final instrumental texture was studied. The added-protein pies obtained would show a series of sensory characteristics that would be potentially related to the satiating capacity expectations they elicited.

3.1. Small-strain rheological measurements of the batters

The batters obtained before cooking were subjected to rheological measurements to ascertain the effect of sample composition on the batter's viscoelasticity. The rheological features of a batter can give a good indication of its structure and, in consequence, of its final performance after baking.

The mechanical spectra of all the batter samples revealed the existence of soft gels, with higher G' values than G'' values and strong frequency dependence throughout the frequency range measured. Fig. 1a shows the mechanical spectra of samples CFF, CLF, W3 and S3. The mechanical spectra of the samples with lower whey protein (W1 and W2) and soy protein (S1 and S2) levels showed similar patterns to samples W3 and S3 respectively, but with lower viscoelastic values.

A Comparison of samples CFF and CLF (without added protein) showed that the full-fat cheese sample behaved as a weaker gel. The two reasons that could underlie this result are, firstly, that the low-fat cheese had a higher protein content than the full-fat cheese (see the ingredient content in Table 1), so it would form a stronger protein network, and secondly, that the full-fat sample (CFF) contained a higher number of fat globules, which deform easily, producing a more deformable matrix.

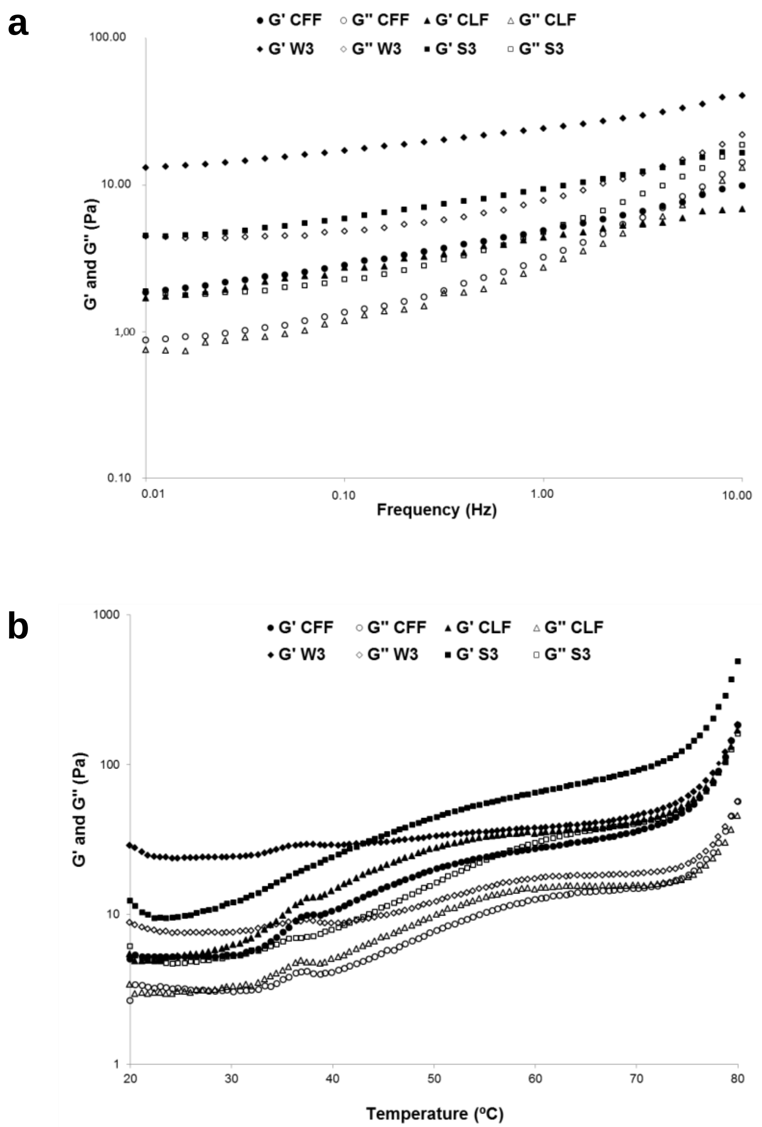


Figure 1. Rheological behavior of the batters without added protein (CFF and CLF) and with the highest protein content (W3 and S4) before cooking. a) Mechanical spectra; b) G' and G'' values as a function of increasing temperature. Heating rate: 1ºC/min ; frequency: 1Hz

Adding WPI (sample W3) caused an evident increase in viscoelastic behavior compared to the control sample (CFF) (Table 2). As previously stated[22] the presence of whey protein in fat-free dairy desserts promotes the formation of stronger gel structure as a result of protein-protein interactions. The functional behavior of milk whey proteins is very complex, caused by interactions between the proteins' intrinsic properties such as composition and amino acid sequence, molecular weight, conformation, flexibility, net charge and hydrophobicity, and extrinsic factors such as temperature, pH and other food components. It was found that adding WPI to low-fat cheese favored the formation of a close, compact protein network.[23]

Table 2. Mean values (n=2) of G', G'' and tgδ at 1 Hz at 20ºC, 60ºC and 80ºC for cheese pie samples. For sample codes see Table 1

Sample	20ºC			60ºC			80ºC		
	G' (Pa)	G'' (Pa)	tgδ	G' (Pa)	G'' (Pa)	tgδ	G' (Pa)	G'' (Pa)	tgδ
CFF	9.0[a]	4.0[a]	0.48[a]	29.2[a]	13.6[a]	0.47[a]	189.8[a]	59.2[a]	0.32[a]
CLF	16.6[a]	5.8[a]	0.46[a]	39.0[a]	17.9[a]	0.46[a]	208.3[a]	62.5[a]	0.22[a]
W3	43.3[a]	11.6[a]	0.48[a]	39.1[a]	18.1[a]	0.36[a]	45.0 [a]	65.3[a]	0.30[a]
S3	10.2[a]	5.5[a]	0.55[a]	62.1[b]	28.9[b]	0.47[a]	324.0[a]	108.1[a]	0.34

[a]Values with different superscript letters in the same column denote statistically significant differences ($p<0.05$)

In contrast, the added-soy protein sample (S3) contained a very similar protein level to W3 but showed weaker viscoelastic behavior, similar to that of the control sample (CFF) (Table 2). A thickening effect of SPC was visible during batter mixing in the preliminary formulation trials, which allowed higher amounts of full-fat cheese to be replaced in the formulation without collapsing the final pie structure. Several studies have demonstrated that heat treatment strongly influences the protein–protein interaction of soy proteins, and also their functional properties, such as gelation.[24] Heat denaturation has been considered the main factor in soy gel formation and the type of gel depends on the heating and cooling conditions, among other factors.

The evolution of the viscoelastic properties as the temperature increased (Fig. 1b) made it possible to predict the behavior of the batters during baking by showing the structural changes that took place. Sample S3 showed the earliest increase in viscoelastic properties with heating, acquiring a strong structure (higher viscoelastic parameter values) at lower temperatures than the other samples. The rest of the batters behaved in a very similar way: a gradual increase in the viscoelastic parameters took place over the heating period due to gelatinization of all the proteins in the batters (egg, milk, and added whey) and at approximately 75ºC a steeper increase in the values indicated the gelatinization of the starch.

Both the mechanical spectra and the thermal behavior of the batters showed the feasibility of using both protein types in the selected amounts to reformulate cheese pies with enhancing satiating capacity.

3.2. Cheese pie instrumental texture measurements

A series of composition factors could influence the final texture of the cheese pie models. The complex variety of ingredients makes it difficult to know exactly which one determines any feature of their final texture. Rather, this is the result of the combination of them all. Besides the starch in the samples, which is probably responsible for part of the structure after reaching its gelatinization temperature, a range of proteins (egg, milk, cheese and added soy or whey protein) are probably the most important factor in determining the final texture of the pies, again due to their denaturation and subsequent gelation. Understanding the properties of specific proteins and ingredients is very useful but is restrictive in predicting performance in real foods[25], where the complexities of ingredients and processing operations have a significant effect on the colloidal structures and therefore on the overall properties of the final food product. One of the most relevant properties of proteins in food systems is their ability to form gels after heating. Heat gelation contributes to textural properties, shapes the product, holds other food components together and retains water in the product. Gelling involves hydrophobic interactions, electrostatic and disulfide bonds. Gelling properties and other functional properties of protein isolates and concentrates are influenced by the physicochemical properties of the proteins, which change as a function of process variables, such as protein concentration, heating temperature and time, ionic strength, and pH.[26]

Fig. 2 shows the behavior of the samples during instrumental texture profile analysis (TPA). The hardness and chewiness parameters (Table 3) clearly show that increasing concentrations of WPI and SPC in the samples produced statistically significant higher values ($p<0.05$) compared with the CFF and CLF samples, with the added-whey protein samples being significantly harder than the added-soy protein samples. In turn, the mean TPA hardness and chewiness values grew significantly higher in the following order: W3 > W2 > W1 and S3 > S2 > S1. The replacement of 50% of full-fat cheese with low-fat cheese (sample CLF) also produced a significant increase in hardness compared to CFF. These results related well to the rheological results for the corresponding batters before cooking, which showed the W3 samples as having the strongest viscoelastic properties, and sample S3 behavior as nearer to that of sample CFF.

In a number of previous studies, different whey proteins' addition has produced harder food matrices. For example, processed cheese analogues prepared with whey protein concentrate (WPC) were found to be harder than those prepared with other proteins,[27] while cheeses to which WPC had been added in connection with partial or total removal of fat had a more compact matrix structure.[19] In the present study, the mean cohesiveness and springiness values did not differ significantly between samples (Table 3). These results indicated that a range of pies with different instrumental textures were obtained by adding whey and soy proteins at different levels without distorting the essential nature of the product.

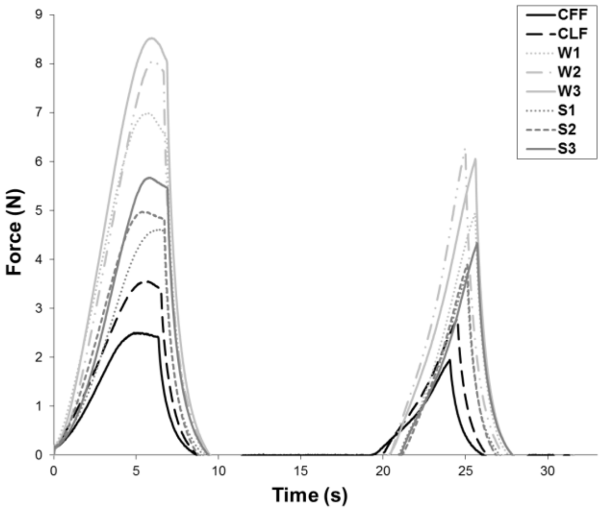


Figure 2. Texture profile analysis (TPA) of the cheese pies without added protein and with the three levels of soy and whey protein

3.3. Consumer tests

3.3.1. Check-all-that-apply (CATA) questionnaire

Although traditional product characterization techniques such as Quantitative Descriptive Analysis provide accurate and reliable information, consumer sensory product characterization methods are interesting options when studying consumer perception[28]. CATA question constitutes a simple and valid approach that is increasingly being used to capture consumer information about sensory and non-sensory perceptions of food products. The present case constitutes a new application of this method to know how the addition of proteins affects a novel, reformulated food product to obtain added value: enhanced satiating capacity along with better nutritional value. This method has the advantage of gathering information on perceived product attributes without requiring scaling, allowing for a slightly less contrived description of the main sensory properties of the product tested.

Table 4 shows the frequency with which each term in the CATA question was selected by the consumers to describe the cheese pies. Significant differences were found in the frequencies of 29 out of the 32 terms related to texture, flavor or use elicited by the samples, suggesting that this type of question was able to detect differences in the consumers' perceptions of the cheese pie samples. No significant differences between samples ($p<0.05$) were found for "Pasty", "Sticky" and "Even if I eat the whole pie I will be hungry shortly", which could probably be due to these attributes were equally relevant for all the samples; also, those three terms had generally a low number of selections (less than 24). There were other attributes also selected by a low number of consumers: "Caramel taste", "Gummy", "Porous texture", "Astringent" and "Soy taste".

With regard to texture terms, the CFF and CLF samples were mostly described by the attributes "Soft", "Creamy", "Tender", "Light", "Moist", "Fondant" and "Spongy". In contrast, samples W1, W3, S1 and S3 were described using words such as "Hard" (W3, S3), "Compact" and "Dry" (both particularly high for W3), "Dense", "Floury" and "Sandy", which reflected opposite texture characteristics. These results were in line with the instrumental texture assessment of the samples, which clearly showed that the added-soy and -whey protein samples were harder and more chewy.

The rheological results that indicated a more solid structure of the whey protein samples and early heat response of the soy protein would indicate that a more solid network was formed by increased-protein samples.

With respect to terms of taste, CFF and CLF samples were mostly described by the attributes “Sweet”, “Cheese taste” and “Milky taste”. These flavor terms were also selected to describe the added-protein samples W1, W3 and S1, but less frequently than for samples CFF and CLF. In contrast, the frequency of use of the terms “Starchy taste" "Earthy taste" although not very high, increased in the added-protein samples, especially in S3, which showed significantly higher frequency of these than the rest of the samples, and also of "Soy taste" and "Astringent". Also, "Off flavor" was significantly higher for S3, selected by 30% of consumers. This increased frequency of selection of negative attributes would probably indicate that soy protein introduces flavor notes which were perceived as striking or out of place in a cheese pie.

Regarding the CATA terms related to the perception of satiating capacity, the consumers selected "If I eat the whole pie I will not be hungry for a long time" more frequently than "Even if I eat the whole pie I will be hungry shortly" and an increase in its frequency was observed in the samples with increased protein concentrations. The consumers selected "I would eat it as a dessert" more frequently than "I would eat it as a snack", indicating that the samples were considered more as complementing a meal than as a snack to be eaten between meals or a meal replacement. This result could be also influenced by the fact that “normal” cheese pie (the base formulation, CFF) is eaten as a dessert and the consumers who completed the CATA question were not aware of the aim of the study or of the sample formulations. Sample S3 had low frequency values for these two terms. In this case, the higher frequency of attributes such as “Off-flavor”, “Starchy taste”, “Soy taste”, and “Floury taste” than for any of the other samples could contribute to consumers' not thinking it could be eaten either as a dessert or as a snack.

Table 4. Frequency of selection of CATA terms for the six cheese pies and Cochran's Q test for significant differences between them. Mean expected satiating capacity mean scores and their significant differences (Tukey's test)

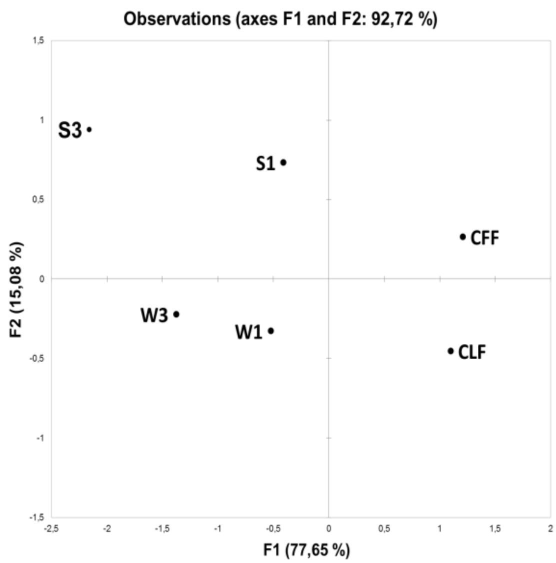
CATA term	Sample						Cochrane's Q
	CFF	CLF	W1	W3	S1	S3	
Sensory terms							
Sweet	54	42	31	18	27	12	<0.0001
Smooth	53	47	16	13	27	5	<0.0001
Soft	47	52	14	6	32	5	<0.0001
Cheese taste	45	39	41	30	22	8	<0.0001
Milky taste	44	38	41	24	31	9	<0.0001
Creamy texture	40	41	11	4	22	3	<0.0001
Tender	39	38	18	10	17	4	<0.0001
Light	37	26	14	7	18	9	<0.0001
Moist	31	36	16	6	17	7	<0.0001
Fondant	28	28	4	8	16	5	<0.0001
Spongy	27	44	7	10	14	8	<0.0001
Grainy	27	16	40	48	25	45	<0.0001
Caramel taste	18	17	11	7	9	5	0.001
Sandy	17	10	29	40	24	34	<0.0001
Pasty*	15	17	24	21	21	25	0.277
Sticky*	15	8	11	16	17	8	0.060
Compact	12	12	39	59	31	43	<0.0001
Starchy taste	9	7	11	12	27	31	<0.0001
Floury	9	10	23	29	31	42	<0.0001
Gummy	8	9	18	22	14	18	0.005
Dry	6	8	32	59	26	52	<0.0001
Dense	6	12	31	34	26	37	<0.0001
Earthy taste	5	5	12	22	12	32	<0.0001
Porous texture	4	15	9	12	24	15	<0.0001

Off flavor	3	11	17	15	16	40	<0.0001
Astringent	1	2	5	6	4	15	<0.0001
Soy taste	0	6	3	5	9	13	<0.0001
Hard	0	4	17	40	10	31	<0.0001
Non-sensory terms							
I would eat it as a dessert	40	47	28	22	24	7	<0.0001
I would eat it as a snack	27	27	21	17	22	10	0.000
Even if I eat the whole pie I will be hungry shortly*	18	9	11	11	14	8	0.075
If I eat the whole pie I will not be hungry for a long time	15	22	24	29	23	21	0.031
Expected satiating capacity scores	5.6^{a}	5.4^{a}	5.8^{a}	6.3^{b}	5.6^{a}	5.9^{a}	

*Indicates a term with no significant differences (Cochran's Q test, p>0.05) among samples; [a.b] Different superscript letters denote significant differences (Tukey's test , p<0.05)

The first two factors of the MFA (Fig. 3) accounted for 92.72 % of the variance of the original dataset, representing 77.65% and 15.08% of the variance respectively. Most of the CATA terms were well represented in the perceptual space defined by the first two factors of the MFA. The first factor (X axis) was related to a series of texture terms such as “soft,” “moist”, or “light”. “Creamy”, “tender” and “fondant” were placed on the right of this axis (positive values) and the evidently contrasting terms “dense”, “compact,” “dry,” “gummy” and “hard” on the left side (negative values). Regarding flavor, the first dimension of the MFA also contrasted “milk taste”, “caramel taste” and “sweet” (positive values) with the terms “astringent”, “earthy taste”, “off-flavor” and “floury taste” (negative values). The second factor of the MFA was mainly correlated to “soy taste” and “starchy taste” (positive values of the Y axis), opposite to “cheese taste” (negative values of the second component).

a



b

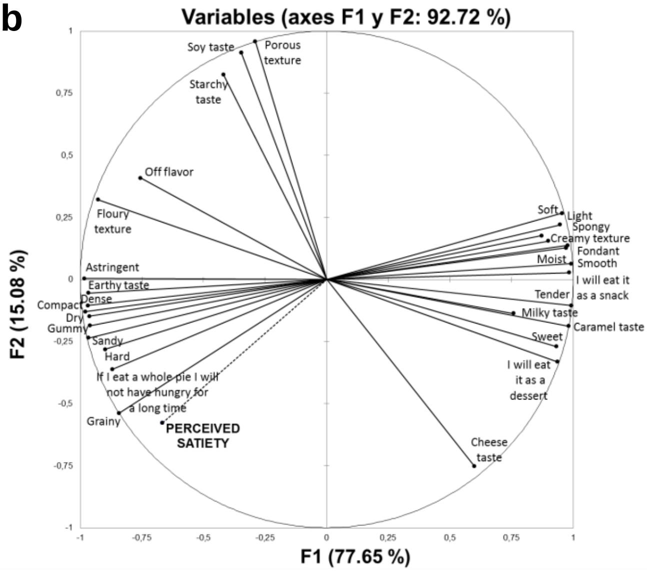


Figure 3. a) Map of terms from the check all that apply (CATA) question; b) Representation of the cheese pies without protein addition and with the highest level of soy and whey protein in the first two dimensions of the Multiple Factor Analysis (MFA) of the CATA counts

The relationship between in vivo aroma release and perception in food products is strongly dependent on the type of texture, relative to two mechanisms: physicochemical mechanisms based on the modification of aroma release and a cognitive mechanism based on aroma-taste-texture interactions. These two mechanisms exist simultaneously but have more or less impact on aroma perception depending on the type of texture.[29]

Finally, the terms related with uses such as “I would eat it as a snack” and “I would eat it as a dessert” were placed in the right side of the X-axis, opposite “If I eat the whole pie I will not be hungry for a long time”.

The products were well differentiated on the first two dimensions. Samples CFF and CLF were close to each other in the area defined by soft, tender samples with a sweet, milky taste. These two samples were the only ones placed on the right side of the sample plot. All the added-protein samples appeared on the left side and were grouped by protein type, in both cases with the more concentrated ones to the left of the least concentrated ones. This indicates that the higher the protein concentration the harder, drier, and more compact the texture. The area defined by the soy-protein samples (S1 and S3) coincided with the flavours not desirable in a milk-based product (upper side), whereas the milk-protein samples (W1 and W3) were placed further away from these flavour features.

3.3.2. Expected satiating capacity assessment

Sample W3 was the only one that elicited a significantly higher expectation of satiating capacity (Table 4). In order to relate the values obtained to the texture and flavour drivers, expected satiating capacity was mapped as a supplementary variable on the MFA (Fig. 3). This means that it was not taken into account during the construction of the factorial axes while the others were considered active, but the statistics for this supplementary variable were obtained by projecting this element onto the active space. The expected satiating capacity position was well in the direction of samples W1 and W3, indicating that the hard, grainy, sandy, dry texture of these samples elicited higher satiating expectations than the lighter texture of the samples without added protein. In particular, when looking at the individual frequencies of mention for the attributes on table 4, W3 was particularly selected as harder, dryer and more compact than the rest of the samples.

The texture features contributed by the addition of protein implied more labour-intensive oral exposure and processing. Previous studies[1] have suggested that particular oral processing characteristics such as a lack of chewing activity contribute to low satiating efficiency of foods. On the other hand, for equal calories, oral-sensory exposure time could contribute to higher satiation within a meal by triggering anticipatory responses. This is because animals, including humans, learn to associate the sensory characteristics of a food with its caloric value post-consumption.[30] These associations are likely to influence explicit expectations about the effect a food will have on appetite, including how filling a food is likely to be (expected satiation) and the extent to which it will stave off hunger until the next meal (expected satiety). Such expectations have been shown to influence appetitive satisfaction and portion size selection.[31] In particular, a previous study[32] found that the expected satiation of semi-solid dairy products increased consistently with increasing thickness. In an extensive review paper on texture and satiation[33], it was concluded that longer sensory exposure times lead to cephalic phase responses that not only contribute to physiological homeostasis but also contribute significantly to satiety.

4. CONCLUSIONS

The satiating effect of protein is recognized worldwide. Consequently, formulating food with the addition of extra protein would seem to be a logical way to enhance the satiating capacity of foods. However, this addition modifies the texture and flavor characteristics of the final products, which in turn influences expectations of satiating capacity. In the present study, a cheese pie was selected as a model food for incorporating different levels of soy and milk whey proteins with the aim of obtaining a range of feasible enhanced satiating capacity products. The results show that the added proteins make the texture harder and drier and move the food away from the sweet and milky flavors that are well-known to consumers. Importantly, these texture characteristics elicited stronger expected satiating capacity, probably due to the longer and more laborious chewing or oral processing needed in order to swallow these samples comfortably. The fact that the addition of whey showed to have an enhanced perception of satiating capacity, without the off-flavors provided by the soy proteins, suggest that whey proteins could be better candidates for reformulation.

The present work opens the door to new strategies for achieving food items with enhanced expectations on satiating capacity, bearing in mind that it is important to deliver matching expectations in the consumers at a very early stage of consumption, as these are drivers of early satiation.

ACKNOWLEDGEMENTS

The authors are grateful to the Spanish Ministry of Science and Innovation for financial support (AGL2012-36753-C02-01). They would also like to thank Mary Georgina Hardinge for assistance in translating and correcting the English manuscript.

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CAPÍTULO III

Does food complexity have a role in eliciting expectations of satiating capacity?

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Food Research International, 75 (2015), 225-232

ABSTRACT

New strategies for formulating healthy, balanced food with enhanced expected satiating capacity are a hot topic. The present work tests the hypothesis that adding complexity to food will result in higher expectations of satiating capacity. Different kinds of “visible” particles (wheat bran, ground coconut, flaxseeds and oat meal) were added to cheese pies with the aim of increasing the complexity of both their appearance and their texture. Two more basic recipes were also prepared with no particles added. Instrumental texture measurements, complexity and expected satiating capacity consumer scoring and sensory profiling of the six pie formulations were performed. In addition, the consumers were asked to write down the characteristics they took into account in their pie complexity scores. For pies with very similar instrumental TPA hardness and resistance to penetration values, a clear trend that emerged was that the more complex the texture, the higher the satiating capacity expectations. The qualitative analysis of the terms mentioned by consumers was of great value for understanding the concepts underlying the appraisal of the samples’ complexity.

Key words: complexity; expected satiating capacity; texture; sensory properties.

1. INTRODUCTION

Identifying strategies to reduce energy intake and enhance satiety during meals is important for effective weight management (Flood-Obbagy & Rolls, 2009). There is an increasing interest in developing food that consumers find desirable in terms of palatability and satiety. “Expected satiety”, i.e. the expectation of the food’s satiating capacity, plays a fundamental role in the actual satiety that is experienced after a food has been consumed. Beliefs and expectations about a recently consumed food can not only have a noticeable influence in the satiety it confers but can also persist well into the inter-meal interval (Brunstrom, Brown, Hinton, Rogers, & Fay, 2011). When compared on a kJ-for-kJ basis, “expected satiation” and “expected satiety” (respectively, the fullness and the respite from hunger that foods are expected to confer) differ markedly across foods. In self-selected meals, they are remarkably good predictors of the energy content of the food that ends up on our plate, and are influenced by the physical characteristics of a food (Brunstrom, 2011).

Texture has an effect on the expected satiating capacity of the food. Hogenkamp, Stafleu, Mars, Brunstrom, & de Graaf (2011) observed that an increase in the perceived thickness of commercial dairy products was positively correlated with the expected satiation they elicited. Higher viscosity in a food leads to longer orosensory stimulation, which may facilitate the learned association between sensory signals and metabolic consequences (Mars, Hogenkamp, Gosses, Stafleu, & De Graaf, 2009). Zijlstra, Mars, de Wijk, Westerterp-Plantenga, Holst, and de Graaf (2009) found a significant effect of a milk-based liquid or semi-solid on fullness, desire to eat, an appetite for something sweet, and prospective consumption, but no clear effect of viscosity on gastro-intestinal hormones.
More solid products require more labor and time in the mouth, causing longer oro-sensory exposure. An increase in oral processing may result in

a greater timespan to allow satiety signals to induce meal termination or evoke satiety (Hogenkamp & Schiöth, 2013). An increase in proxies of orosensory exposure (eating rate, oral processing behavior) may result in an increase in nutrient-energy-sensing, and give a longer timespan for satiety signals to reach the brain. Forde, van Kuijk, Thaler, de Graaf, and Martin (2013), working with a set of solid savory meal components, found that oral exposure time was highly correlated with the total number of chews, while the chewing rate was relatively constant. They concluded that for equal calories within a meal, oral-sensory exposure time could contribute to higher satiation.

Increasing complexity of food texture could also be an interesting strategy for prolonging oral exposure. Complexity is not an easily defined concept. According to Mielby, Jensen, Edelenbos, and Thybo (2013), problems often arise when trying to measure perceived complexity, as it can be difficult to know what is actually measured, especially since defining complexity is a hard task. A large part of the research on food complexity deals with different flavor stimuli (Schifferstein, 1992; Kroeze, 1990; Sunarharum, Williams, & Smyth, 2014). In a study relating complexity and liking, Lévy, MacRae and Köster (2006) stated that in previous work familiarity (and liking) had been measured with the aim of deducing the perceived complexity. According to these authors, “familiarity” is a very unclear concept that may either refer to the frequency with which this particular stimulus has been encountered or to the extent to which the stimulus resembles other known stimuli, and that “familiarity” and “novelty” should not to be considered as the two extremes of one single dimension. In addition, they advised taking into account the *relative* perceived complexity (or the distance to the optimally liked perceived complexity) in liking studies. Less work has been done on texture complexity (normally combined with flavor) (Bitnes, Ueland, Møller, & Martens, 2009). For example, Weijzen, Zandstra, Alfieri, & de Graaf (2008) selected four commercially available snacks which were “clearly different in taste and texture”, and Mielby, Jensen, Edelenbos, & Thybo (2013) studied visual appearance complexity with mixed fruit images. Porcherot and Issanchou (1998), working with five experimental crackers varying in flavor but “identical in composition, shape and texture”, asked consumers to score the crackers on a number of scales: Simple/ Complex, Easy to describe/ Difficult to describe, Composed of few ingredients/ Composed of a lot of ingredients, and Mind few sensations/ Mind a lot of sensations, among others. One important point to be considered is that the stimuli that vary in an experiment inevitably vary in other dimensions apart from perceived complexity, leading to difficulty in interpreting the data. However, results reported by Mielby, Kildegaard, Gabrielsen, Edelenbos and Thybo (2012) indicate that despite individual differences, we all have some sort of common understanding of what seems more or less “complex”. A simple way of measuring perceived complexity, validated by several authors, is to ask the subjects directly how complex they perceive the product to be (Moskowitz & Barre, 1977; Sulmont-Rossé, Chabanet, Issanchou, & Köster, 2008; Weijzen, *et al.*, 2008).

The present study was conducted as a case study with cheese pies. It aimed to relate complexity to perceived expected satiating capacity the of cheese pies. Four samples were formulated with the same basic recipe but adding different visible food particles (wheat bran, ground coconut, whole flaxseeds and oat meal). The hypothesis was that adding different kinds of “visible” particles would increase the complexity of both the cheese pie appearance and the texture which in turn would increase its expectations on satiating capacity. Two additional pies were prepared, one with the basic recipe and another with dairy cream added to the basic recipe. Consumers rated both the complexity and the expected satiating capacity of all the samples, and then responded to an open question about the cheese pie characteristics that they considered when evaluating complexity. The answers were analyzed to know underlying concepts about complexity. In addition, instrumental texture characteristics of the cheese pies, and their sensory characteristics, obtained through flash profiling, were analyzed and correlated with both complexity and satiating capacity.

2. MATERIALS AND METHODS

2.1. Sample ingredients

Cheese pies (Table 1) were prepared following the basic recipe described in Marcano, Varela and Fiszman (2015). Four formulations were prepared by adding different particulate ingredients (PI) to increase both the visual and in-mouth perception of pie complexity. These ingredients were wheat bran (Fraga S. A., Huesca, Spain) (sample WB), ground coconut (Casa Pons, Valencia, Spain) (sample CO), flaxseed (Int-Salim; Barcelona, Spain) (sample FX) and oat flakes (Brueggen, Lübeck, Germany) (sample OF). Sample B (basic recipe) and sample C (basic recipe with the addition of dairy cream, Lectiber, 15 g fat/ 100g, León, Spain) were also prepared. The remaining ingredients, common to all the formulations, were: full-fat fresh cheese (starter-free, pasteurized, protein content 10.9 g/100g, moisture 72 g/100g and fat 14 g/100g as declared by the supplier, Hacendado, Spain), pasteurized liquid whole egg (Ovocity, Valencia, Spain), sucrose (Acor, Valladolid, Spain), maize starch (Maizena®, Barcelona, Spain), and skimmed milk powder (Central Lechera Asturiana, Siero, Spain).

Table 1. Composition of the cheese pies

Ingredient (g/100g)	Sample					
	B	**C**	**WB**	**CO**	**FX**	**OF**
Fresh cheese	55.0	34.1	52.2	52.2	52.2	52.2
Egg	20.0	12.4	19.0	19.0	19.0	19.0
Sucrose	10.0	6.2	9.5	9.5	9.5	9.5
Skimmed milk	10.0	6.2	9.5	9.5	9.5	9.5
Corn starch	5.0	3.1	4.6	4.8	4.8	4.8
Dairy cream	0.0	38.0	0.0	0.0	0.0	0.0
Wheat bran	0.0	0.0	5.0	0.0	0.0	0.0
Ground coconut	0.0	0.0	0.0	5.0	0.0	0.0
Flaxseeds	0.0	0.0	0.0	0.0	5.0	0.0
Oat bran	0.0	0.0	0.0	0.0	0.0	5.0
Fat content	9.8	17.5	9.7	9.7	9.7	9.7

B: basic recipe; C, WB, CO, FX, and OF: basic recipe with the addition of cream, wheat bran, ground coconut, flaxseeds, and oat flakes respectively

2.2. Sample preparation

2.2.1 Batter preparation

The batter was prepared in a mixer (Kenwood Major Classic, UK), at top speed (580 rpm). The cheese was whisked for 1 min, then the egg and sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water and the starch dispersed in it. In the case of sample C, the cream was added to the water, milk and starch mixture. This liquid was added to the batter mixture, which was beaten for a further 1 min. Lastly, the particulate ingredient (if any) was added and the final mixture was beaten for 17 min. A total of 20 min processing was used for all formulations.

2.2.2. Baking

The batter was poured into a heat-resistant silicone mold for five rounded pies (7 cm in diameter and 3,5 cm in height) and baked for 25 min at 180ºC in an electric oven (De Dietrich, Basingstoke, UK), preheated for 15 min. The oven, the tray and the tray position in the oven were identical in each case. The pies were left to cool at room temperature for 1 h, then demolded and stored in refrigeration (4 ºC) for 24 h before the measurements were made.

Small adjustments to the ingredient addition order and mixing time were needed to obtain stable pies after baking. These adjustments differed in each case.

2.3. Particulate ingredient (PI) characterization

2.3.1. PI dry bulk

Eight grams of the dry PI were placed in a 50-ml graduated cylinder and the volume was read (Mongeau, 1982). Dry bulk was expressed as ml/ g. Mean values were obtained from three replicates.

2.3.2. PI swelling

One gram of the dry PI was hydrated in 10 ml of distilled water in a calibrated cylinder at room temperature. After 18 hours, the bed volume was recorded and expressed as volume/g original sample dry weight (Robertson, De-Monredon, Dysseler, Guillon, Amado, & Thibault, 2000), with some modifications). Mean values were obtained from three replicates.

2.3.3. PI water retention capacity (WRC)

The WRC of the PI was determined according to the method described by Robertson, *et al*., 2000), with some modifications. One g of the PI was weighed precisely in a graduated centrifuge tube and 30 mL of distilled water were added. After 18 h at room temperature the samples were centrifuged (3000xg) for 20 min. The supernatant was decanted and the tube carefully inverted to leave the pellet to drain in the tube. WRC was calculated as the amount of water retained by the pellet (g/ g dry weight). Mean values were obtained from three replicates.

2.3.4. PI particle size and distribution

A laser diffraction particle size analyzer (Mastersizer 3000, Malvern Instruments, Ltd., Worcestershire, UK) was used to characterize the PI particle size and distribution. The following descriptive variables were recorded: D(4,3), the mean diameter of equivalent volume or mass, which indicates the central point of the volume distribution of the particles; Dv(50), the mass median diameter of the volume distribution, such that 50% of the sample is smaller and 50% larger than the value obtained; Dv(10), such that 10% of the sample mass is composed of smaller particles than the value obtained; and Dv(90), such that 90% of the sample mass is composed of smaller particles than the value obtained. D(10) and D(90) indicate the range of values in which 80% of the particles in each sample moves. The Dv(90) values of the PIs were not very different (Table 2), although the coconut particles were significantly smaller and had a wider size distribution (Dv(10) = 711 µm), followed by wheat bran. The flaxseeds presented the narrowest particle size range. The particle size of the oat flakes could not be measured because it exceeded the 0.1 to 3500 µm range of the equipment. Mean values were obtained from two replicates.

2.4. Instrumental texture measurement

Textural Profile Analysis (TPA) and penetration tests were carried out at 10°C, considered the consumption temperature, using a TA.XT.Plus Texture Analyser (Stable Micro Systems; Godalming, UK), with P/75 probes and the simulated upper incisor probe (HDP/VB) respectively. For TPA, an assay of double compression, 4 cylindrical samples (height 1.7 cm, diameter 2.2 cm) of each formulation obtained from pies from different batches prepared on different days were compressed to 40% of their initial height at 1 mm/s, with 5 s of rest time between the two compression cycles and a trigger force of 15 g. Their hardness (in N), springiness, cohesiveness, and chewiness (in N) were recorded using the Texture Expert software. The penetration test measured the maximum force (Fmax, in N) needed to penetrate the sample and the deformability (Def, in mm) as the deformation achieved before penetration occurred. For this test, two whole pies prepared on different days were penetrated twice in different positions at 1 mm/s, with a trigger force of 15 g and a probe travelling distance of 10 mm.

2.5. Sensory analysis

2.5.1. Perceived complexity and expected satiating capacity

Eighty consumers participated in the evaluation and scoring of perceived *Complexity* and *Expected satiating capacity*. The consumers (55 women and 25 men, aged between 20 and 64 years) assessed the six samples, which were presented at 10 ± 1 °C on small plastic plates labelled with random three-digit numbers in a sequential monadic series, following a complete block design balanced for carry-over position effects; they received no information about the scope of the project. The consumers'

Complexity and *Expected Satiating Capacity* ratings for the six cheese pies were obtained on 9-point scales (respectively labelled 1 = not complex at all to 9 = very complex, and 1 = ”If I ate this whole pie it would not fill me at all” to 9 = ”If I ate this whole pie it would fill me a lot”). Since the cheese pies were cut into eight wedge-shape pieces, the consumers could easily figure out the size of the whole cheese pie. After completing the evaluation, the consumers answered the question: “What characteristics did you consider in your evaluation of the complexity of the cheese pies?” in an open box. The information was compiled and analyzed qualitatively to discuss how consumers evaluated complexity and its potential relation with satiating capacity.

2.5.2. Flash profiling

Flash profiling – a combination of free-choice term selection with a ranking method – was applied. The simultaneous presentation of the six samples allowed direct sensory comparison (Dairou & Siefffermann, 2002).

2.5.2.1. Panel

Flash profiling was carried out by 20 assessors (13 women and 7 men, aged 21-45 years) recruited among students and employees of the Institute of Agrochemistry and Food Technology (IATA-CSIC) and the Polytechnic University of Valencia who had experience in the sensory description of dairy products.

2.5.2.2. Procedure

Flash profiling was performed in a standardized sensory analysis test room (ISO, 2007) in two sessions. In the first, each panelist was explained the procedure and given a printed didactic example of descriptive ranking

(Delarue, 2014) of apples for several attributes. In the second session, after looking at the samples and tasting them, each panelist generated his/her own list of attributes to describe the differences among the six cheese pie samples. The panelists were told to focus on any non-hedonic attributes they would consider appropriate to describe the samples, providing they were sufficiently discriminative to allow ranking of the samples, or at least a partial ranking, since ties were allowed. No indication was given regarding the number of attributes they should propose. They then rated the six samples (on ordinal scales ranging from 0 = "none or little' to 10 = "a lot") for each attribute on their own list. Each panelist was presented with the whole sample set simultaneously. The samples (one eighth of a pie) were served at consumption temperature (10 ± 1 °C) on small white plastic plates coded with random three-digit numbers. Mineral water was provided for rinsing the mouth between samples.

2.6. Data analysis

One way analysis of variance (ANOVA) and Fisher's test were applied to study the variability among the samples in the TPA and penetration instrumental tests, and in the complexity and expected satiating capacity ratings; ANOVA was used to determine the significance of the inter-sample differences ($\alpha = 0.05$) (Statgraphics Centurion 15, StatPoint Technologies, Inc. Warrenton, VA, USA). Generalised Procrustes Analysis (GPA) was performed on the flash profile ranking data to generate the factorial map used to evaluate the overall sensory positioning of the products as perceived by the panelists. To interpret this positioning in terms of sensory attributes, the loading plot corresponding to the factorial map was obtained. To identify the samples and terms most closely related to the cheese pie expected satiating capacity and complexity a multifactorial analysis (MFA) was performed using these variables as supplementary. In addition to know the relationship between the sensory attributes and the instrumental texture variables these latter were also used as supplementary (XL-STAT (2014.5.03, Addinsoft, Paris, France).

All the full words (with lexical meaning) mentioned by the participants in answer to the question about complexity were considered in the data analysis. Firstly, the raw data were translated into English. Taking into account that the participants answered in complete sentences, the key-words identifying one characteristic for defining complexity were listed. A search for recurrent terms was performed, and terms with similar meaning were grouped into categories. The data were evaluated by three different researchers with a minimum of 2 years' experience in consumer research, who interpreted the meaning and synonymy of the words personally. To balance out the subjective influences of individuals, they then met, reached an agreement on their classifications, and consensually determined (Ares & Deliza, 2010) the final categories and their names as presented in this paper.

The existence of statistical differences in the frequency of mention of the categories and terms was evaluated using a chi-square test. A chi-square per cell test was then used to identify the source of variation of the global chi-square (Symoneaux, Galmarini, & Mehinagic, 2012).

3. RESULTS AND DISCUSSION

3.1. PI characterization

The PI characteristics measured are shown in Table 2. All the values are significantly different. The wheat bran particles had significantly the highest WRC and dry bulk and the lowest swelling characteristics, whereas oat flakes showed the lowest WRC and the highest swelling.

Table 2. Characterization of the particulate ingredients

Parameter	Particulate ingredient			
	Wheat bran	**Coconut**	**Flaxseed**	**Oat flakes**
Dry bulk (ml/g)	5.00^{d}	3.00^{c}	2.20^{a}	2.50^{b}
Swelling (ml/ g)	1.40^{a}	1.70^{b}	2.50^{c}	2.60^{d}
WRC (g water retained/ g dry sample)	4.98^{d}	3.23^{c}	2.65^{b}	1.95^{a}
Laser Diffraction (µm)				
D(4,3)	1740^{b}	1490^{a}	1940^{c}	*
Dv(50)	1670^{b}	1380^{a}	1880^{c}	*
Dv(10)	974^{b}	711^{a}	1270^{c}	*
Dv(90)	2660^{b}	2480^{a}	2690^{b}	*

WRC: Water retention capacity; D (4,3): De Brouckere mean diameter; Dv (50): median diameter of the volume; Dv (10): 10% of the particles are smaller than this value; Dv (90): 90% of the particles are smaller than this value. The particle size of the oat flakes was greater than the equipment could quantify (diameter equivalent>3500 µm)

3.2. Cheese pie instrumental texture analysis

The behavior of the samples is shown through the double cycle compression test (TPA) parameter values in Table 3. The addition of cream (sample C) produced a significantly softer pie compared with the basic recipe (sample B). This was probably because the cream supplied extra fat and water to the system (sample C batter presented the highest fat content, see Table 1). Similar results were reported by Kaminarides, Nestoratos, and Massouras (2013), who obtained softer cheese products when cream was added to the formulation, suggesting that fat weakened the protein network (Walstra & Jenness, 1984). The addition of the PIs produced cheese pies with statistically significant ($p<0.05$) higher hardness and chewiness values (these two parameters are closely related) compared with sample B. This result was in line with the fact that all the PI samples swelled in water and showed some extent of WRC (Table 2), which partially restricted the water availability, therefore creating drier, more compact final structures. Sample OF showed the highest hardness and chewiness values (Table 3), and oat flakes had the highest swelling value (Table 2), whereas samples WB, CO and FX showed no significant differences in hardness values. Examples of the addition of coarse particles (mostly insoluble fiber) to dairy desserts are scarce, so comparison proved difficult. Although some significant differences were found in the other TPA parameter values of the samples, the variations were very small.

The penetration parameter Fmax presented the same trend as TPA hardness, with sample C as significantly the softest and less deformable, and sample OF the most resistant to penetration (Table 3). Deformability – which is an index of the capability of the sample to deform before penetration occurs – decreased when fat was added. In a study using eight model cheese products with a variety of compositions, Panouillé, Saint-Eve, Loubens, Déléris, and Souchon (2011) also found that fracture strain decreased in the samples prepared with milk fat.

Table 3. Mean values of the texture profile analysis (TPA) and penetration test parameters of the cheese pie samples

Test	Parameter	Sample					
		B	C	WB	CO	FX	OF
TPA	Hardness (N)	3.45^{c}	1.42^{d}	4.62^{b}	4.44^{b}	5.00^{b}	7.59^{a}
	Springiness	0.59^{b}	0.66^{a}	0.62^{ab}	0.61^{ab}	0.66^{a}	0.67^{a}
	Cohesiveness	0.41^{b}	0.45^{ab}	0.45^{ab}	0.46^{ab}	0.48^{a}	0.46^{ab}
	Chewiness (N)	0.87^{cd}	0.49^{d}	1.11^{c}	1.03^{c}	1.63^{b}	2.40^{a}
Penetration	Fmax (N)	0.95^{c}	0.34^{d}	1.26^{b}	1.25^{b}	1.26^{b}	1.73^{a}
	Def (mm)	2.8^{b}	2.3^{a}	4.4^{c}	4.3^{c}	4.6^{cd}	4.9^{d}

Different superscript letters in the same row denote values with statistically significant differences (P-value < 0.05). TPA: texture profile analysis; Fmax: maximum force needed to penetrate the sample; Def: deformation achieved before penetration occurred

3.3. Perceived complexity and expected satiating capacity

3.3.1. Scoring for complexity and expected satiating capacity

The consumer (n=80) scores for the pies' complexity and expected satiating capacity are shown in Table 4. Sample WB was rated as significantly the most complex, followed by sample FX. Sample OF was rated as significantly less complex than samples WB and FX and not significantly different from sample CO. Although samples OF and CO had visible particles, they were white and integrated into the pie mass, especially the coconut which probably elicited lower perception of complexity than darker, visible particles as wheat bran or flax seeds. Finally, samples B and C, the two with no PI added, were rated with the lowest values and as equally complex.

Table 4. Mean consumer (n=80) scores for Complexity and Expected Satiating Capacity of the six cheese pie samples

Score	Sample					
	B	C	WB	CO	FX	OF
Complexity	2.5^{a}	2.3^{a}	7.8^{d}	5.1^{b}	6.4^{c}	5.4^{b}
Expected satiating capacity	4.3^{b}	2.3^{a}	6.8^{d}	5.2^{b}	6.1^{c}	7.5^{e}

[a.b] Different superscript letters within the same row denote significant differences ($p<0.05$)

The expected satiating capacity scores were completely aligned with the TPA hardness and penetration Fmax values from the instrumental texture assessment, in the following order: OF>WB>FX>CO>B>C. It is very well known that texture makes major contributions to expected satiating capacity evaluation (Hogenkamp *et al*., 2011). Texture characteristics such as hardness, compactness and dryness were previously found to be well correlated with a higher expected satiating capacity which in turn could be related to the fact that these textures are more laborious to handle in the mouth and lead to longer oro-sensory exposure (Marcano *et al*., 2015).

This alignment with textural features could be easily seen in sample OF, significantly the hardest and most deformable (Table 3); although its complexity score was similar to that of sample CO (an intermediate value), it obtained significantly the highest score for expected satiating capacity.
At the other extreme, samples B and C both were rated as equally complex, but sample C, which was significantly softer and less deformable (Table 3), scored significantly lower on expected satiating capacity.

The finding that is worth noting in the present study is that for samples CO, WB and FX, which had no significantly different instrumental hardness (TPA) and Fmax (penetration test) (Table 3), the samples that obtained significantly higher complexity scores (WB>FX>CO) also obtained significantly higher expected satiating capacity scores in the same order. The authors are aware that instrumental texture features, especially in the present case, do not account for difficulty in mastication (which is certainly a textural feature too) that is due principally to the presence of particles. Two pies with similar instrumental hardness could be different in their in-mouth handling difficulty, leading to different oral exposure and, in consequence, to a different expected satiating capacity. The presence of big particles (sample WB) or seeds (sample FX) probably increased the complexity scores of these samples, not only because of their non-homogeneous appearance but also because of the complex mastication they implied.

3.3.2. Terms generated to characterize complexity

In order to understand and discuss the pie complexity scoring and its relation with expected satiating capacity, a qualitative analysis was made of the terms elicited when after scoring the six samples, the consumers were asked what characteristics of the pie they considered in their evaluation of complexity. From the sentences and words written down by the consumers, a total of 54 terms were extracted. Each panelist generated between 4 and 9 terms.

After the qualitative analysis, the terms were grouped into four categories by three researchers, working independently. The terms were grouped according to their relation to: a) *Texture*, b) *PI detection*, c) *Flavor,* and d) *In-mouth perception*. The categories that contained most terms were *Texture* (18 terms) and *PI detection* (15 terms) (Table 5). In addition, the number of times the terms in these two categories were mentioned was not significantly different. In other words, the consumers used both *Texture* and *PI detection* terms spontaneously, and with the same frequency, as characteristics to evaluate complexity.

Within the *Texture* category, the most frequently mentioned terms were the generic term “Texture” (12.6%) and the opposite terms “Homogeneous”/ “Heterogeneous” (6.1%), which were counted together as two extremes of the same semantic concept. These results indicated that texture and homogeneity (or the lack of it) were the most relevant sensory characteristic taken into account in judging the complexity of the complete set of pies. Other terms were mentioned less frequently, like the “Compact” / “Spongy” pair of opposites, and “Hard”.

Within the *PI detection* category, terms related with the presence and amount of added components that were unfamiliar in cheese pies were elicited. The most frequently mentioned terms were “Appearance”, “Presence”, “Component”, “Different”, and “Amount” (all referring to the PI). By simple observation of the samples it could be seen that the addition of a PI made the pies look very different from samples B and C (with no PI addition). The latter had a very light-yellowish, homogeneous look to the naked eye and a familiar, very fine granular visual texture when observing the cut surface, because of the tiny cheese granules that build up the pie mass. Sample CO had a rougher, granular appearance because of the presence of the ground coconut particles, but since they are white they appeared to be well integrated into the cheese pie mass. Sample OF had a slightly darker yellowish color than the basic recipe B (and C), and although the oat fiber particles were the largest, their high swelling value (Table 2) made them not at all “evident” when the sample was observed, as the swollen oat fiber particles were “disguised” in the pie mass. In contrast, sample FX presented obvious dark brown flaxseeds evenly distributed through the whole pie mass, which retained the basic cheese pie color and appearance. The flaxseeds’ swelling value was higher than that of the other particles (Table 2), and when hydrated into the pie presented a higher volume than the raw material, with a clear, mucilaginous, transparent film surrounding them. They were also significantly the biggest in size and had the narrowest size range of those measured (Table 2), probably because all the particles were whole seeds.

Finally, sample WB was the darkest: all the pie mass was light brown in color and contained clearly visible light brown particles. The wheat bran particles had the largest size range (Table 2), so both large and small particles were present. This was probably the reason for the darker color of the WB pie, and for the fact that although the wheat bran particles were as evident as the flaxseeds, not all of them could be observed individually.

Flavor was the third category in number of terms generated (13). Flavor terms were mentioned with the same frequency as the *In-mouth sensations* category (34 times each). The most-mentioned by far was the generic term "Flavor", indicating that different flavor notes were detected across the complete set of samples but not explicitly mentioned. This probably means that the addition of the different PIs communicated some flavors that were different from the milky, classic cheese pie flavor of the basic recipe (sample B) but were not easy to identify: the PIs had mild flavors, especially if they were well integrated into the pie. "Coconut" was the most frequently mentioned individual flavor, although with a low frequency (4 times).

Finally, the category that generated the fewest terms was *In-mouth sensations* (10), although the frequency of mentions was the same as for *Flavour* (34). "In- mouth", "Perception" and "Chewing" and the opposites "Easy"/ "Difficult" (to chew) were the most frequently mentioned terms related to handling and bolus formation in the mouth. Although the terms related to in-mouth manipulation were probably closely related to texture appraisal, it was decided to group them as a separate category because the consumers referred to them specifically and they probably involved some texture characteristics that were not closely related to the instrumental tests.

Table 5. Terms generated by the consumers when asked about the pie characteristics they considered when evaluating complexity. Qualitative term categories, terms generated within each category, total number of terms and mentions within each category, and number of mentions of each term

Qualitative category and terms	Number of terms*	Number of mentions*
Texture	18 (32.1%)	59[a] (29.8%)
Texture		25 (12.6)
Homogeneous/ Heterogeneous		12 (6.1)
Hard		4 (2.0)
Compact/ Spongy		4 (2.0)
Crumbly		3 (1.5)
Other: Soft, Solid, Consistent, Smooth, Cohesive, Crunchy, Moist, Lumpy, Fibrous, Pasty, Grainy		1 (0.5) each
PI detection	15 terms (26.7%)	71[a] (35.9%)
Appearance		13 (6.5)
Presence		10 (5.1)
Different		9 (4.5)
Component		8 (4.0)
Amount		7 (3.5)
With fiber		5 (3.0)
Particles		4 (2.0)
Seeds		4 (2.0)
Structure		2 (1.0)
Addition		2 (1.0)
Color		2 (1.0)
Strange		2 (1.0)
Other: New, Varied, Distribution		1 (0.5) each
Flavor	13 terms (23.2%)	34[b] (17.2%)
Taste/ flavor		18 (9.0)
Coconut		4 (2.0)
Sweet		2 (1.0)
Odor		2 (1.0)
Other: Egg, Caramel, Milk, Bread, Cereal, Salty, Sour, Neutral		1 (0.5) each

Qualitative category and terms	Number of terms*	Number of mentions*
In mouth sensations	10 terms (17.9%)	34^{b} (17.2%)
In-mouth		9 (4.6)
Perception		6 (3.0)
Chewing		6 (3.0)
Easy/ Difficult		5 (2.5)
Evolution		4 (2.0)
Other: Simultaneous, Identify, Intense, Fullness		1 (0.5) each
Global total	**56 (100%)**	**198 (100%)**

* Percentage values between parentheses; ^{a,b} Different superscript letters denote values with statistically significant differences (P-value < 0.05)

3.4. Flash Profile (FP)

Figures 1A and 1B respectively show the sample configuration and attribute biplots obtained by GPA. The first and second factor accounted for 72.38% of the variance of the experimental data (51.22% and 21.16% respectively). The six samples were distributed over the four quadrants of the sample map. Samples WB, FX and OF were placed at negative values of the first factor (Figure 1A). Satiating capacity and complexity (used as supplementary variables in MFA) were also placed in the negative half of the first factor not very far to each other and similar length of their vectors indicating some good degree of correlation.

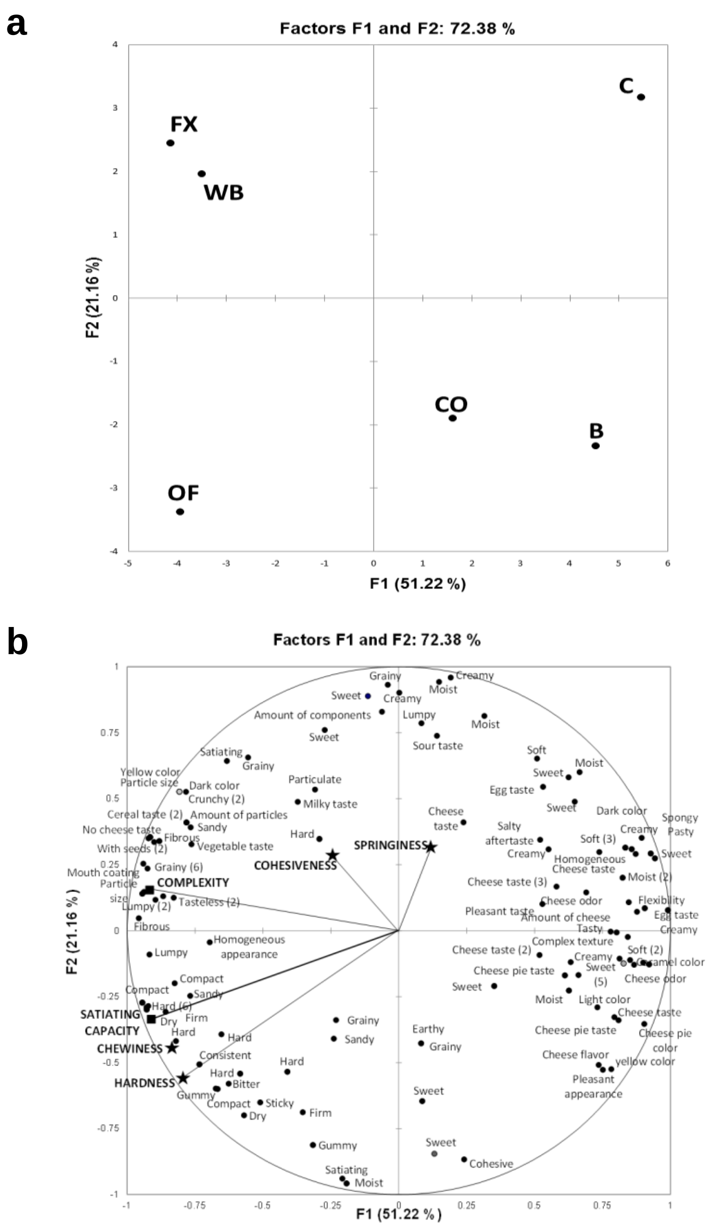

Figure 1. (a) GPA maps of the samples obtained from the Flash Profile test (FP). (b) MFA Analysis map of attributes obtained from the FP test (satiating capacity, complexity and variables of instrumental texture: hardness, springiness, cohesiveness, chewiness and maximum force of penetration, plotted as supplementary variables)

Samples WB and FX were very close to each other at negative values of the first factor but at positive values of the second. The latter samples were near descriptors such as “Grainy”, “Particles”, “Amount of particles”, “Particle size”, “With seeds”, “Sandy”, “Crunchy”, “Dark color”, all these attributes related to particle presence, and “Yellow color” and “Cereal taste”. It seemed that the presence of clearly visible dark particles (and probably their detection in the mouth) governed the descriptors of these two samples that were highly correlated with Complexity (the level of correlation is also indicated by the length of the vector). Samples WB and FX obtained the highest complexity scores (Table 4) and were grouped together on the sample map. The analysis of the terms elicited in the open question about complexity characteristics indicated that those related to particles were the most frequently mentioned by consumers (Table 5).

Far from these two samples (and from the area dominated by PI-related characteristics on the perceptual map), although at negative values of the first factor, was sample OF, described as “Compact”, “Hard”, “Firm”, “Sticky”, “Gummy”, “Dry”, “Consistent”, “Grainy” and “Sandy” (Figure 1). These are all texture descriptors, indicative that in this case the texture determined the placement of sample OF on the map. All of them were good correlated to Satiating capacity (sample OF obtained the highest Satiating capacity score, Table 4). The oat flakes presented the highest swelling and the largest particle size (Table 2). In addition, whatever the kilning and flaking processes, they contain β-glucan, a major component of oat endosperm cell walls, which probably immobilized some water during the batter preparation and pie baking (Rebello et al., 2014), contributing a drier, harder texture. In fact TPA hardness and chewiness, and Fmax and deformability from the penetration test appeared very near in the same quadrant (Figure 1B) and highly correlated with Satiating capacity (the level of the correlation is indicated by the length of the vectors on the plot,

Figure 1B) showing that resistant-to-mastication textures are important cues for expectations on satiety.

Samples B, C and CO were placed at the positive values of the first factor. Samples CO and B were placed at the negative values of the second factor, with CO to the left of B, indicating that it possessed more particulate ingredient characteristics than B (and than C, which was placed even more to the right, at positive values of the first factor). Taste and flavor dominated the descriptive terms for samples B and CO: “Cheese taste”, “Egg taste ”, “Sweet”, “Cheese pie taste”, “Cheese pie color”, “Light color”, “Pleasant appearance”, all of which are traditional, familiar terms for cheese pies. Ground coconut seemed to be considered more suitable for cheese pies than the other PIs, probably because it matched the expectations of a traditional or conventional cheese pie flavor better, and this was more important than the presence of detectable particles.

Finally, sample C was placed in an isolated position at very positive values of both the first and the second factor. “Moist”, “Creamy”, “Spongy”, and “Soft” were the principal texture features that described this sample which was opposed to sample OF in the map (Figure 1A). TPA springiness was also placed in the quadrant of positive values of both first and second factors in line with the sensory description of sample C, and opposed to OF whereas cohesiveness seemed to be complementary (orthogonal position) and pointing to samples WB and FX. “Sweet”, “Cheese taste” and “Egg taste” were the flavor attributes mentioned as its characteristics. All of these define a conventional cheese pie. As commented above, this sample was prepared with cream, which contributed a softer texture. In a previous paper (Marcano, Ares & Fiszman, 2015) comparing cheese pie samples, some lacking one of the basic ingredients (without starch, without sugar or without egg) with samples with added soy or whey proteins, it was also found that the samples that had retained the typical cheese pie characteristics were segregated from those which shared atypical texture or flavor features.

An analysis of the whole scenario indicated that complexity was an important factor in eliciting satiating expectations for samples with similar resistance to mastication, being those samples perceived as more complex the perceived as more satiating. Samples CO, WB and FX, obtained no significantly different values of TPA hardness and maximum force of penetration indicating that the three had very similar texture features; however, CO complexity rating was significantly lower than those for the samples WB and FX, and in consequence it was placed far (and in the opposed quadrant) in the perceptual map near sample B (without particles) and far from the satiating capacity vector (Figure 1).

4. CONCLUSIONS

In the present study, visible particles were added as a way to increase (both appearance and texture) complexity perception in cheese pies. The aim was to check if the perception of complexity contributes expectations about satiating capacity.

It was clearly shown that for samples with similar instrumental hardness and resistance to penetration, an appreciation of higher complexity elicited higher expectations of satiating capacity. In addition, the qualitative analysis of the terms that the consumers spontaneously mentioned they had taken into account in assessing the complexity of the pies proved a good tool for understanding what underlies the complexity concept. The most frequently-mentioned terms were those related to the particle characteristics and to texture.

Further research is needed to confirm the present hypothesis about higher complexity/higher expectation of satiating capacity, which could be a new strategy for formulating well-balanced food with enhanced satiating capacity to reduce energy intake. The authors of the present paper consider it has exploratory value.

ACKNOWLEDGEMENTS

The authors are grateful to the Spanish Ministry of Economy and Competitiveness for financial support (AGL2012-36753-C02-01). They would also like to thank Mary Georgina Hardinge for assistance in correcting the English manuscript and Mario Martinez from the University of Valladolid for the particle size analysis.

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CAPÍTULO IV

In vitro measurements of intragastric rheological properties and their relationships with the potential satiating capacity of cheese pies with konjac glucomannan

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Food Hydrocolloids, 51 (2015), 16-22

ABSTRACT

Konjac glucomannan (KGM) is consistently associated with creating a sense of fullness while slowing down physiological processes associated with food digestion and nutrient absorption. Formulating food with KGM is difficult because it develops very high viscosity in aqueous solution. In the present study, cheese pies containing increasing amounts of KGM were prepared in such a way that the gum was not fully hydrated. The aim was to achieve formulations with high doses of KGM and to delay development of the gum's rheological properties until it reaches the gastric tract. The pies and the gum alone were then submitted to oral plus gastric *in vitro* digestion and their rheological properties were measured and compared. The viscoelastic properties increased as the KGM content of the pies rose. In addition, the digested pies were more effective at forming solid-like structures than the digested gum alone at the same concentration. The instrumental texture measurements of the pies indicated that higher KGM levels produced harder and more cohesive pies. These texture attributes would potentially enhance the expected satiating capacity of the pies. When 118 consumers with no information about the pies' composition or the health benefits of KGM performed a hedonic sensory test, their liking for the pies decreased in line with the increases in KGM level in high-KGM formulations.

Key words: glucomannan; intragastric viscosity; satiating capacity; cheese pie

1. INTRODUCTION

Konjac glucomannan (KGM) is a very well-known water-soluble type of fibre composed of a straight chain of β-1→4 D-mannose and D-glucose units in a ratio of 1.6:1, with a small amount of branching (8 %) through β-(1→6)-glucosyl linkages. It is derived from the tuberous roots of the konjac plant (*Amorphophallus konjac* K. Koch), native to Asian countries such as China, Japan and Thailand. Konjac flour, extracted from the corm, has a long history of food use in Asia and is used in Far Eastern cuisine to make noodles, tofu and snacks (Chua, Baldwin, Hocking, & Chan, 2010). KGM is the main constituent of konjac flour (50 to 98 g/ 100 g content) (Fang & Wu, 2004). To date, the most common KGM purification methods involve ethanol extraction, due to its simplicity and efficiency (Takigami, 2000). This method could be notably improved using hydration followed by precipitation and freeze-drying (Chua, Chan, Hocking, Williams, Perrya, & Baldwin, 2012).

KGM is non-digestible in the human small intestine. It has a high molecular weight (200-2000 kDa) and high viscosity in a water solution. As a food additive, it is used as an emulsifier, thickener, meat binder, etc. in a number of food applications. Examples include a gel property enhancer in low-quality surimi (Liu, Wang, & Ding, 2013a; Iglesias-Otero, Borderías, & Tovar, 2010), egg white gel (Liu *et al*., 2013b) and noodles (Zhou *et al.*, 2013) and a fat replacer in meat products (Jimenez-Colmenero, Triki, Herrero, Rodríguez-Salas, & Ruiz-Capillas, 2013; Ruiz-Capillas, Triki, Herrero, Rodriguez-Salas, & Jiménez-Colmenero, 2012) and in mayonnaise (Li, Wang, Jin, Zhou, & Li,, 2014).

KGM is also consumed in capsules or in powder form as dietary fibre supplement (Keithley & Swanson, 2005). A number of effects of this substance on human health have been reported. KGM affects total cholesterol and fasting blood glucose beneficially (Sood, Baker, & Coleman, 2008; Guardamagna, Abello, Cagliero, & Visioli, 2013). Although its therapeutic uses need further investigation, glucomannan could be a candidate for treating a range of physiological disorders such as diverticulitis, Crohn's disease or ulcerative colitis (Tester & Al-Ghazzewi, 2013).

The present study focuses on the properties of KGM as a satiating agent. In its Scientific Opinion on the substantiation of health claims related to KGM and reduction of body weight (EFSA, 2010), the Panel on Dietetic Products, Nutrition and Allergies of the European Food Safety Authority "noted that glucomannan forms a viscous, gel-like mass in the stomach when hydrated, and that this 'mass effect' could delay gastric emptying and induce satiety leading to a decrease in subsequent energy intake". It considered that reduction of body weight is a beneficial physiological effect for overweight individuals and concluded that "a cause and effect relationship has been established between the consumption of glucomannan and the reduction of body weight in the context of an energy-restricted diet." According to Vuksan *et al.* (2009), KGM, like other viscous fibres, has volumetric effects, creating a sense of fullness while slowing down physiological processes associated with food digestion and nutrient absorption. Several studies have concluded that when administered in capsules, a daily base dose of KGM can promote increased weight loss and satiety (McCarty, 2002).

According to Keithley and Swanson (2005), KGM may promote satiety via several mechanisms: increased mastication effort, postulated to induce cephalic- and gastric-phase signals that induce satiety; delayed gastric emptying; slowed small-bowel transit time; slowed absorption of food in the small intestine leading to attenuated postprandial insulin surges; and accelerated delivery of food to the terminal ileum, where satiety signals are transmitted. A number of intervention studies in which KGM was supplied found increased satiety and weight reduction (Salas-Salvadó, *et al.*, 2008; Lyon & Reichert, 2010). Sukkar *et al.* (2013) found that a mixture of dairy proteins and glucomannan reduced eating desire. They concluded that this effect was related, besides other hormonal factors, to the presence of KGM, which forms a “net” after gelling in the acid milieu of the stomach. The viscosity of a newly-made KGM solution develops gradually over long periods of time and reaches a peak depending on particular characteristics like the degree of acetylation (Du, Li, Chen, & Li, 2012) or geographical origin (Fang & Wu, 2004).

Some KGM-based products (made almost exclusively of KGM) such as noodles and other pasta-like items are currently on the market. They are essentially designed as weight-control food products because they contain very few calories. However, references in the literature to real solid foods with KGM added to enhance their satiating capacity are scarce. In the present work a cheese pie was used as a vehicle to add KGM. This cheese pie is a refrigerated dairy dessert with a soft, gel-like texture. It could be eaten as a snack between meals. Its high protein content gives it a high satiating capacity *per se* and offers a good basis for adding ingredients/ additives that could enhance this property.

The hypothesis of the present study was that adding KGM to the cheese pie in such a way that gum hydration would be not favoured during pie processing and baking but would take place in the intragastric digestion phase would increase the viscosity of the digesta and deliver its satiating capacity properties *in situ*.

Dikeman and Fahey (2006) reviewed the literature on the viscosity measurements of fluid digesta from the stomach of monogastric animals.

They concluded that this was a complex and difficult task. In their opinion, viscosity in the gastrointestinal tract of animals has not been measured adequately since shear rate may vary considerably with sampling location, individual animal, meal composition, and gut motility. In addition, many papers have reported apparent digesta viscosity values measured at a single shear rate values, which is not correct since the material would normally exhibit pseudoplastic behaviour. *In vitro* methods simulating digestion processes are widely used to study the gastrointestinal behaviour of food. Although human nutritional studies are still considered the “gold standard” for addressing diet-related questions, *in vitro* methods have the advantage of being more rapid, less expensive and less labour intensive and of not being subject to ethical restrictions (Minekus *et al*., 2014). *In vitro* methods try to mimic *in vivo* physiological conditions, taking into account the presence of digestive enzymes and their concentrations, pH, digestion time and salt concentrations, among other factors. Static models of human digestion have been used to address such diverse scientific subjects as digestibility and bioaccessibility and, to a much lesser extent, to assess viscosity development or gelation in the gastric tract. Other approaches have taken into consideration the development of viscosity over time (enabling hydrocolloid hydration). For instance, Vuksan *et al.* (2009) measured the viscosity of three preload drinks containing three different hydrocolloids, including glucomannan, at 15 min intervals over 90 min, to estimate their hydration time. However, they only reported single measurements at a single shear rate and did not consider any behaviour change due to shear strain or any effect of the gastric enzymes.

The present study aimed to assess the effect of adding increasing amounts of konjac glucomannan (KGM) on the rheological behaviour of cheese pies digested orally plus gastrically *in vitro*. The effects of the KGM ingredient alone and a KGM commercial product were also compared. In addition, the instrumental texture of the KGM cheese pies and consumer liking for them were assessed and compared with those of a control recipe.

2. MATERIALS AND METHODS

2.1. Cheese pie formulations

Table 1. Formulation of cheese pie samples

Ingredient	Sample*				
	B	**K1**	**K2**	**K3**	**K4**
Fresh cheese	55.00	-	-	-	-
Low-fat fresh cheese	-	57.46	57.03	56.59	56.16
Whole egg	20.00	20.90	20.74	20.58	20.42
Sugar	10.00	10.45	10.37	10.29	10.21
Skimmed milk	10.00	10.45	10.37	10.29	10.21
Corn starch	5.00	-	-	-	-
KGM	-	0.75	1.50	2.25	3.00
Total	100.00	100.00	100.00	100.00	100.00
Protein content (g/100g)	9.2	10.4	10.3	10.3	10.2
Fat content (g/100g)	9.8	2.4	2.3	2.3	2.3
Calories (cal/100g)	196.7	120.6	119.7	118.8	117.9

***** KGM: Konjac glucomannan; B: control sample without KGM; K1, K2, K3, and K4: samples containing 0.75, 1.5, 2.25, and 3 g KGM /100g, respectively

A control cheese pie sample (B) was prepared with full-fat fresh cheese (starter-free, pasteurized, protein content 10.9 g/100 g, moisture 72 g/100 g and 14 g fat /100 g, as declared by the supplier, Hacendado, Spain), native maize starch (Maizena®, Barcelona, Spain), pasteurized liquid whole egg (Ovocity, Valencia, Spain), sucrose (Acor, Valladolid, Spain) and skimmed milk powder (Central Lechera Asturiana, Siero, Spain) (Table 1). Four cheese pie samples were formulated with different amounts of KGM (konjac glucomannan 90.5 g/ 100 g, Trades S.A, Barcelona, Spain)

(Table 1). During the mixing process, it was observed that the viscosity of the mixture increased considerably with the addition of KGM, making it too thick and difficult to handle, so the full-fat cheese was replaced by low-fat cheese (starter-free, pasteurized, 12.3 g protein /100 g, moisture 83 g/100 g and 0.2 g fat /100 g, as declared by the supplier, Hacendado, Spain) and the corn starch was removed from these samples (K1, K2, K3 and K4), to obtain pies with a more similar texture to the control. This achieved a moister mix as well as a beneficial reduction in calorie content (Table 1). A control pie prepared from low-fat cheese without KGM would yield a similar fat content and hence a similar calorie content to the pies containing KGM. However, it was not possible to replace the full-fat cheese with low-fat cheese since the pie collapsed after baking.

2.2. Sample preparation

2.2.1. Batter preparation

The samples were prepared in a mixer (Kenwood Major Classic, UK). For the basic batter recipe (B), the cheese was whisked for 1 min at top speed (580 rpm), then the egg and sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water (9 g/ 100 g water) and the starch was dispersed in it. These were added to the mixture, which was beaten for a further 17 min. The total processing time was 20 min. For the batters with KGM, the cheese was whisked for 1 min, then the egg and half the sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water (9 g/ 100 g water) and the KGM was mixed with the remaining half of the sugar and added to the mixture, which was beaten for a further 1 min. The total processing time was 5 min.

2.2.2. Baking

Each batter was poured into a heat-resistant silicone mould for five rounded pies (7 cm in diameter and 3.5 cm in height) and baked for 25 min at 180 °C in an electric oven (De Dietrich, Basingstoke, UK), preheated for 15 min. The oven, the tray and the tray position in the oven were identical in each case. The pies were left to cool at room temperature for 1 h, then demoulded and stored in refrigeration (4 °C) for 24 h before the measurements were made.

2.3. Instrumental texture measurements of the cheese pies

The instrumental texture measurements were made with a TA.XT.plus Texture Analyser (Stable Microsystems, Godalming, UK). Each cheese pie formulation was prepared twice, on different days. Three cylindrical pieces were cut from each pie with a round biscuit cutter. The top and bottom of each cylinder were discarded, leaving cylindrical pieces 22 mm in diameter and 17 mm in height. A double compression test (texture profile analysis, TPA) was performed at 10 °C (consumption temperature) with a flat-ended cylindrical probe (P/75) to reach 40% compression (6.8 mm of probe traveling distance) at a speed of 1 mm/s, with a 5 s waiting time between the two cycles. The parameters obtained from the curves were hardness (in N), springiness, cohesiveness, and chewiness (in N), using the Texture Expert software (version 6.0.6.0).

2.4. *In vitro* oral plus gastric digestion

2.4.1. Artificial saliva

Artificial saliva was prepared according to the method described by Morell, Fiszman, Varela, and Hernando (2014). All the reagents were of analytical grade. The components were sodium bicarbonate (5.208 g/ L), potassium phosphate dibasic trihydrate (1.369 g/ L), sodium chloride (0.877 g/ L), potassium chloride (0.477 g/ L), calcium chloride dehydrate (0.441 g/ L), mucin from porcine stomach type II (PGM) (Sigma, M2378) (2.16 g/L), α-amylase type VI-B from porcine pancreas (Sigma, A3176) (8.70 g/L, 200.000 units), and HPLC grade double-distilled water. The *in vitro* oral digestion was performed with a saliva to sample ratio of 1:4 on a weight basis.

2.4.2. *In vitro* digestion of the samples

To simulate gastric digestion, an adaptation of the *in vitro* digestion model proposed by Abdel-Aal (2008) was used. This model consists of a jacketed glass reactor (1000 mL capacity) with continuous magnetic stirring, maintained at 37 °C by its temperature-controlled circulating water bath throughout the test.

Each pie (approximately 110 g) was weighed, mixed with simulated gastric fluid (SGF, a 0.034M NaCl solution) in a proportion of 50 mL SGF/ 100 g pie and ground in a blade-grinder (Ufesa, model U1EBB, Barcelona, Spain) for 15 s. The slurry was then sieved to 0.5 mm and 100 g was digested. At this point, artificial saliva was added to sample B (the only sample that contained starch). After 10 s the pH value was reduced to 1.9 with HCl 10 N, and pepsin (P7125, pepsin from porcine gastric mucosa, ≥ 400 units/ mg protein, Sigma-Aldrich) was added. The ratio of pepsin to protein (egg plus cheese) was 1:250 on a weight basis. The mix was maintained at 37 °C with continuous stirring at 400 rpm for 30 min. The digestion was stopped by raising the pH to 7.5 with NaOH (1 M) (Abdel-Aal, 2008).

The ability of the KGM ingredient alone (sample K) and of a KGM-based food supplement (sample Kc, Bicentury®, Girona, Spain) to develop viscosity when submitted to *in vitro* gastric digestion was also analysed for comparative purposes. In each case, the amount containing 1 g of KGM was diluted with 200 mL distilled water and immediately subjected to *in vitro* stomach digestion, since these products did not require an oral digestion phase. The complete stomach protocol was followed except for the addition of pepsin (as no protein was present). The amounts of KGM and water were selected by following the dose recommended on the commercial product's package.

After the simulated digestive process, all the samples were maintained at 37 °C until the rheological measurements were performed a few minutes later. All the tests were run in duplicate with samples prepared on different days.

2.5. Small-strain rheological measurements of the *in vitro* digestion products

A controlled stress rheometer (AR-G2, TA-Instruments, Crawley, UK) was used. The strain applied was selected to guarantee the existence of linear viscoelastic response according to preliminary stress sweeps performed in all the samples. The samples were allowed to rest in the measurement cell for a 5 min equilibration time. A 40-mm diameter plate-plate sensor geometry with a serrated surface and a 1 mm gap was employed. Vaseline oil was applied to the exposed surfaces of the samples to prevent sample drying during testing. Mechanical spectra, the storage modulus (G') and the loss modulus (G'') in the linear region from 10 to 0.01 Hz at 37 °C (temperature of the stomach during digestion) were recorded. Each sample was measured in duplicate, prepared on different days. The data were recorded using TA data analysis software (Rheology Advantage™ software, version V5.7.0, T.A. Instruments, New Castle, DE, USA).

2.6. Consumer tests

All the sensory tests were carried out in the sensory laboratories of the Institute of Agrochemistry and Food Technology (IATA-CSIC) and the Polytechnic University of Valencia, both of which are equipped with individual booths. The tests were conducted with 118 consumers in total (62% female, ages ranging between 18 and 53 years). The pies were cut into eight wedge-shaped pieces. One piece of each sample (B, K1, K2, K3 and K4) was presented in a sequential monadic series, in a single session, following a balanced complete block experimental design (William's design). The samples were served at 10 °C (consumption temperature) in small plastic trays coded with random three-digit numbers. The consumers scored their liking for the appearance, flavour and texture and their overall liking for each sample on a 9-box hedonic scale ranging from 1 = I don't like it at all to 9 = I like it very much. The panellists were instructed to rinse their mouths with water after each sample assessment. No information about the ingredients of the cheese pies was given to the participants.

2.7. Data analysis

Analyses of variance (ANOVA) were performed to compare the effect of adding different concentrations of KGM on instrumental texture and rheological parameters, global appearance, flavour, texture and overall acceptance of the cheese pie samples. Fisher's LSD test was applied to evaluate the statistically significant differences between the means (α=0.05) of the samples. The statistical analyses were performed with Statgraphics Centurion XVI (Warrenton, Virginia, USA).

3. RESULTS AND DISCUSSION

3.1. Cheese pie instrumental texture measurements

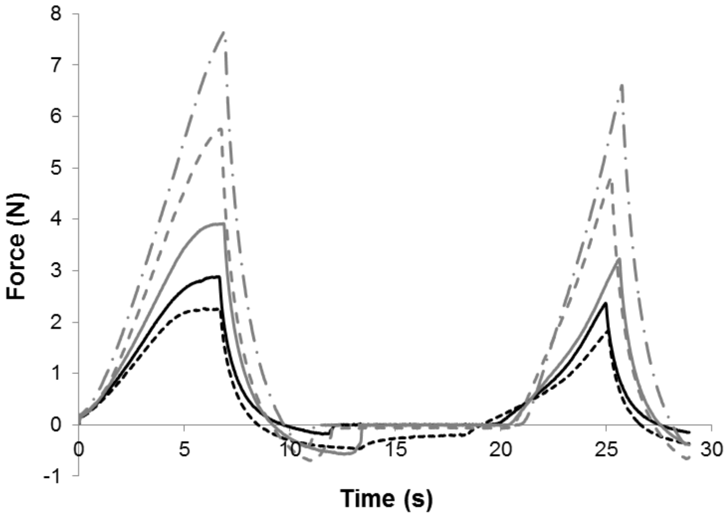

Figure 1.- Texture profile analysis (TPA) of the cheese pies control (B) and with the four levels of KGM (K1, K2, K3 and K4). B: ; K1: ; K2: ,K3: and K4:

Figure 1 shows the behaviour of the samples during instrumental texture profile analysis (TPA). Increasing concentrations of KGM produced statistically significant higher values ($p<0.05$) of hardness and chewiness (which is closely related to hardness) compared with sample B (Table 2). It is worth noting that the lowest level of KGM (sample K1) gave a significantly lower ($p<0.05$) hardness value than sample B. The principal difference between control sample B and all the samples containing KGM is that the K samples were prepared with low-fat cheese and with no starch. Yang, Liu, Ashton, Gorczyca, and Kasapis (2013) found that binary mixtures of whey protein (15 g/ 100 g) with increasing amounts of wheat starch led to stronger networks (higher hardness values) at high levels of starch. In these authors' opinion, at high levels of starch the binary systems created phase separation and the overall level of water available in each polymeric phase decreased, leading to a higher effective concentration of whey protein in that phase. The role of the starch in sample B could be envisaged as having the same effect. On the other hand, even though the KGM was added to the cheese pie batters in a way that barely allowed its hydration, its role in the final systems would probably be to restrict water availability to some extent. This would create more compact structures as its concentration rose, leading to higher pie hardness values (Table 2). In a previous study with noodles made from low-protein wheat flour (Zhou *et al*., 2013), the addition of KGM (up to 5 g/ 100 g) significantly increased the noodles' sensory firmness. The explanation related KGM with limitations on the noodle starch's swelling and interference with gluten network development: as a neutral polysaccharide, KGM seemed to act more as a steric spacer. An increase in gel strength ranging from 0 to 1.5 g/ 100 g was reported for surimi with KGM added (Liu *et al*., 2013a).

Table 2. Mean values of the texture profile analysis (TPA) parameters of the cheese pie samples

Sample	TPA parameters			
	Hardness(N)	Springiness	Cohesiveness	Chewiness(N)
B	2.97^{b}	0.70^{a}	0.44^{a}	0.92^{a}
K1	2.30^{a}	0.86^{b}	0.46^{a}	0.92^{a}
K2	3.78^{c}	0.83^{b}	0.57^{b}	1.78^{b}
K3	5.59^{d}	0.71^{a}	0.58^{b}	2.32^{c}
K4	7.59^{e}	0.71^{a}	0.62^{c}	3.32^{d}

Different superscript letters in the same column denote values with statistically significant differences (P-value<0.05; 95% confidence)

Cohesiveness values increased significantly with KGM addition. In the TPA curves (Figure 1) it can be seen that the macrostructure of samples B, K1, and K2 underwent more damage (an incipient plateau in the force values could be observed before reaching the preselected strain value of 40% of the initial height of the samples), so lower cohesiveness values could be expected. Sample B presented the lowest springiness (Table 2), while the samples containing less KGM (K1 and K2) presented significantly higher values than sample B for this parameter. Springiness decreased as the KGM concentration rose, reaching values not significantly different ($p>0.05$) from B at the higher KGM concentrations (samples K3 and K4). In samples with an internal structure, lower levels of KGM seemed to enable them to recover their initial height, probably because the protein (egg and cheese) networks were the dominant structural features that governed their mechanical behaviour, while the starch in sample B (5 g/ 100 g) and the KGM (with the highest contents in samples K3 and K4) would act as fillers in the protein network, subtracting elastic recoverability. Yang, *et al.* (2013) described the morphology of polymeric mixtures of whey protein and wheat starch as having the protein forming a continuous phase and starch the discontinuous filler. Cheese pie systems have a restricted availability of water for starch to swell. Consequently, sample B would have partially swollen starch granules embedded in the protein network, increasing their compactness.

3.2 Small-strain rheological measurements of the *in vitro* digestion products

The first step was to compare the performance of KGM alone and of the KGM-pies. The mechanical spectra (Figure 2) for the KGM ingredient alone (sample K) and the commercial KGM food supplement (sample Kc) after gastric phase digestion showed a change in their behaviour over the experimental frequency range, from predominantly liquid-like at low frequency ($G'' > G'$) to predominantly solid-like ($G' > G''$) at high frequency. This response to change over the time-scale of deformation under oscillatory shear indicated that these dispersions containing 1 g/ 100 g KGM behaved as random coil polymer solutions (Robinson, Ross-Murphy,

& Morris, 1982). In other polysaccharides like galactomannan, at relatively high concentrations a liquid-like behaviour has also been observed at low frequencies, while at higher frequencies the system behaved like a solid, and the cross-over frequency (where G′ equals G″) typically moved to lower frequency values when the concentration increased (Sittikijyothin, Torres, & Gonçalves, 2005). In the present study the cross-over frequency values of samples K and Kc were practically the same, demonstrating a very similar relaxation time.

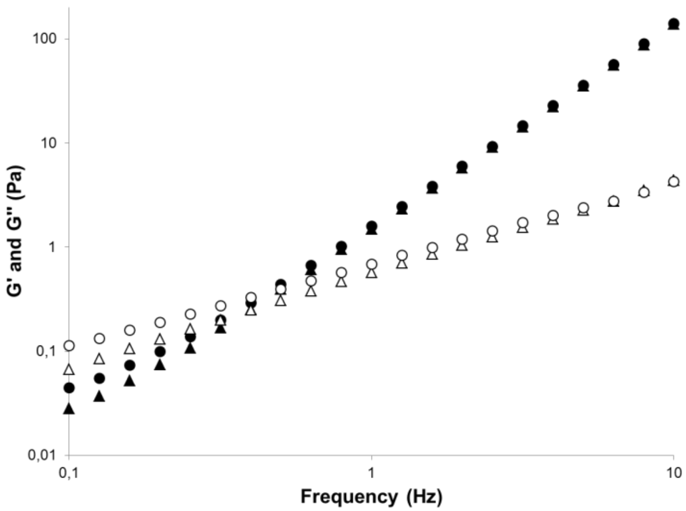

Figure 2. Mechanical spectra of the KGM ingredient alone (sample K) and the commercial KGM product (sample Kc) after gastric phase digestion. Circle: K and triangle: Kc ; closed symbols: G’ and opened symbols: G’’

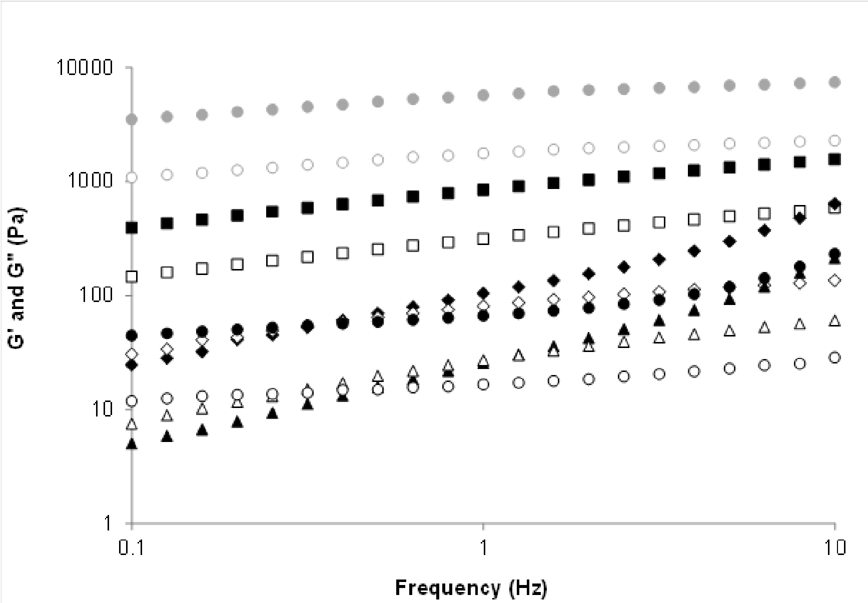

Figure 3. Mechanical spectra of the fresh cheese pie samples (B, K1, K2, K3 and K4) after gastric phase digestion. Black circle: B, triangle: K1, diamond: K2, square: K3 and gray circle: K4; closed symbols: G' and opened symbols: G''

Table 3. Mean values (n=2) of G', G'' and tgδ at 1 Hz at 37ºC for the in vitro diggestion products of fresh cheese pies samples (B, K1, K2, K3 and K4) and experimental and commercial dispersions (K and Kc)

Samples	1 Hz, 37ºC		
	G' (Pa)	G'' (Pa)	tg δ
B	56.73^{a}	14.91^{a}	0.27^{a}
K1	27.41^{a}	27.61^{a}	1.01^{d}
K2	113.20^{ab}	87.13^{a}	0.77^{c}
K3	1106.50^{abc}	473.00^{b}	0.44^{b}
K4	4624.50^{d}	1771.50^{c}	0.39^{b}
K	1.59^{c}	0.69^{a}	0.43^{b}
Kc	1.52^{bc}	0.68^{a}	0.45^{b}

Different superscript letters in the same column denote values with statistically significant differences (P-value<0.05; 95% confidence)

The viscoelastic properties of the pie samples were assessed immediately after in vitro oral plus gastric digestion. The mechanical spectra performed at 37°C showed clear differences in the viscoelastic behaviour of the samples (Figure 3). Sample B, composed of all the cheese pie's basic ingredients (Table 1) including full-fat cheese and corn starch and with no KGM, showed a weak gel-type viscoelastic behaviour. Its G' (elastic component) values were greater than its G'' (viscous component) values, i.e. it exhibited a prevalently solid-like behaviour. It is worth noting that both viscoelastic moduli presented very low values over the complete range of frequencies tested, denoting a weak structure. It should also be pointed out that the samples were submitted to oral plus gastric *in vitro* digestion simulation with the objective of finding out about the development of enhanced rheological properties owing to the presence of KGM (including sample B for comparison). No further evaluation of the extent of these digestion phases' effect on protein or other components was performed.

Digested samples K1 and K2, which contained 0.75 and 1.5 g KGM / 100 g respectively, presented the same behaviour pattern as samples K and Kc (described above) but had higher G' and G'' moduli values. In consequence, the viscoelastic behaviour of these samples might be thought to be governed essentially by the KGM, with the remaining digested cheese pie particles contributing some structure to the system. In the same way, when the KGM content was higher (samples K3 and K4, with 2.75 and 3.00 g KGM/ 100 g respectively) the mechanical spectra showed a weak gel-like behaviour over the whole frequency range studied for both samples (Figure 3). Also, the moduli values were significantly higher than in samples K1 and K2 and were further apart. The moduli values increased by two decades between samples K1 and K4 (Table 3), denoting a more structured system, and the tan δ values decreased correspondingly as the KGM content increased between K1 and K4 (Table 3). This result should be highlighted since the potential satiating effect of adding KGM to cheese pies would be higher than that of the ingredient alone (in powder form or in capsules). Tobin, Fitzsimons, Chaurin, Kelly, and Fenelon (2012) reported that the mechanical spectra for gelled mixtures containing 11 g whey protein isolate (WPI) / 100 g and 0.5 g KGM / 100 g also showed that G' values were greater than G'' throughout the frequency range tested (0.1-100 rad/s) and that these values were less frequency dependent than those of the WPI gel alone, indicating a more solid-like behaviour. In addition, the G' value of the mixed systems increased as the level of KGM addition increased. In the same study, confocal microscopy showed phase separation of WPI-KGM solutions into large irregular shaped konjac inclusions within a continuous WPI gel. In the same way, Liu, Wang and Ding (2013a) obtained significant increases in the gel properties of low quality surimi after the addition of seven levels of KGM. The gel strength of the surimi sample with 1.50 g KGM / 100 g was higher than that of the surimi samples without KGM. As the KGM content increased, the gel properties of the surimi increased significantly. They attributed this effect to a possible interaction between KGM and myofibrillar protein to form a viscoelastic three-dimensional structure, or to the KGM and myofibrillar protein conjugation's displaying better gel properties. Zhou *et al*. (2013) also explained the reinforced texture of the cooked KGM-added noodles as being due to integration of the KGM into the gluten network, imparting integrity to a fragile network structure. This more solid behaviour would contribute gastric distension and, in consequence, a delay in gastric emptying.

In the present study, only the rheological behaviour displayed by KGM alone and KGM in a real food system during *in vivo* oral plus gastric digestion phases was considered, since this is the main factor attributed to konjac glucomannan as a satiating capacity enhancer. Other factors that could also affect the results, such as particle size and distribution derived from the simulated mastication and digestion processes, total time, total volume, use of gastric lipase, shaking, decreasing pH profile, etc., were not taken into account. However, as suggested by Zhang and Vardhanabhuti (2014), the presence of a polysaccharide in the protein matrix could induce physical and conformational changes in the protein, thus affecting its digestibility by altering the accessibility of the cleavage sites to protease. In turn, as the intragastric KGM gel would delay gastric emptying, the digestion (aminoacid profile) of the protein would change. All these points suggest that further studies should be conducted on this topic.

Besides the higher viscoelastic functions developed by the KGM cheese pies, two more advantages of the proposed systems might be pinpointed: one is the fact that these cheese pies provide a small amount of calories (Table 1) along with a high level of protein (the macronutrient with the highest satiating power); the other is that a real food could be more appealing than capsules or other pharmaceutical-type presentations. Henson, Cranfield, and Herath (2010) stated that belief in the efficacy of functional ingredients plays a critical role in determining the propensity to consume them. They also considered that the results of using phytosterols (in relation to perceptions of impacts on blood cholesterol levels and the personal risk of cardiovascular diseases) suggest that the perceived effectiveness differs appreciably according to the product into which they are incorporated. Consequently, the ‘bottom line’ is that functional ingredients must not only be perceived to work but must also be delivered in a form that consumers consider appropriate.

3.3 Consumer liking test

Table 3. Results of acceptance assessment

Attribute	Sample*				
	B	K1	K2	K3	K4
General appearance	6.13^{a} (1.48)	6.20^{a} (6.20)	5.85^{ab} (1.47)	5.71^{b} (1.50)	5.51^{b} (1.50)
Flavor	6.70^{a} (1.63)	5.67^{b} (2.10)	5.21^{b} (1.91)	4.45^{c} (1.83)	3.79^{d} (1.99)
Texture	6.08^{a} (1.87)	5.71^{a} (1.82)	4.86^{b} (1.97)	4.48^{b} (1.95)	3.39^{c} (1.69)
Global acceptance	6.24^{a} (1.61)	5.81^{a} (1.59)	5.09^{b} (1.71)	4.58^{c} (1.74)	3.99^{d} (1.92)

Different superscript letters in the same row denote values with statistically significant differences

A hedonic test was performed to discover whether the addition of KGM affected the perception of liking for the pies. In general, a decrease in liking was obtained as the KGM content increased (Table 4). No significant differences were found between samples B and K1 ($p>0.05$) regarding appearance, texture or overall liking, but a gradual decrease in liking was found as the KGM content of the sample formulation rose. Jimenez-Colmenero*, et al*. (2013) found that reformulating dry fermented sausages by adding KGM to replace fat produced a decreased in acceptability. Ruiz-Capillas *et al.* (2012) reported that because of the KGM addition, the water-binding properties of konjac materials would lead to the release of fewer fluids during chewing, resulting in less juiciness, which would be related to harder and drier systems.

A recent study on consumer perceptions of cheese pies with satiating capacity using the projective mapping technique (Marcano, Ares, & Fiszman, 2015) included samples B and K3. Sample K3 was related to texture terms such as mouth-coating, gummy and pasty and to taste terms such as tasteless and no cheese pie taste, while sample B was found to be sweet, with a taste described as cheese, dairy, fresh-cheese pie and pleasant, and its texture was associated with terms such as good, smooth, creamy, soft, moist, spongy, and fondant. These authors found that sample B, with the "appropriate" and expected characteristics of a cheese pie (prepared with the typical basic formulation), was familiar and acceptable to consumers, while sample K3 (prepared by adding 2.25 g KGM/ 100 g) was considered less suitable due to sensory characteristics that were unexpected in cheese pies.

From the point of view of eliciting satiating capacity, however, it is well known that foods in liquid form elicit weaker physiological responses associated with satiety than more solid forms. There is evidence for this in terms of cognitive effects, oral processing and gastric emptying time, among other factors (Tucker & Mattes, 2013). One explanation is that information present at the time of consumption generates expectations which modulate post-ingestive (actual) satiety processes and that because of the KGM addition, the overall experience of satiety reflects this integration of cognitive, sensory and nutrient-induced cues (Yeomans, McCrickerd, Brunstrom, & Chambers, 2014). As a result, harder, more compact textures that require increased oral activity to chew the product and to form a ready-to-swallow bolus would contribute higher satiating expectations than lighter, softer textures.

On the other hand, sensory flavour characteristics are normally not responsible for eliciting satiating power. Hogenkamp, Stafleu, Mars, Brunstrom, and de Graaf (2011) found that the expected satiation of dairy products increased consistently with increasing thickness, whereas flavour characteristics did not change the expected satiation effects. At all events, changing the flavour profile of a dairy dessert by adding a number of aroma compounds is a relatively easy task.

It is worth noting that the consumers who participated in the present study were not aware of the cheese pies' composition. The results of the sensory appraisal of the cheese pie samples with KGM indicated that, as in any new functional food development, further communication efforts will be needed to focus the consumers' attention on evidence that products containing the functional ingredient actually are efficient. Consumers could then decide their own balance between indulgence and health benefits. Although consumers tend to prefer health benefits in carriers that have an image or history of healthiness (van Kleef, van Trijp, & Luning, 2005), where there is an evident relationship between satiating capacity and weight loss, as in the present case, indulgence (cheese pies) should play a role.

4. CONCLUSIONS

Glucomannan develops very high viscosity values in aqueous solution. This fact has a negative effect on the possibility of using it to formulate satiating food. In the present study, the gum was added to cheese pies in such a way that the gum was not fully hydrated and therefore had no adverse effects during the processing of the pies before baking. The pies subjected to *in vitro* oral plus gastric digestion successfully developed weak gels, which became stronger as the KGM level in the pies rose. Increasing the KGM levels produced harder and more cohesive pies. This effect would be useful for eliciting higher expected satiating capacity at the time of consumption because of the increase in mouth handling time and effort. However, consumer liking decreased as the KGM content increased. Further consumer studies in which the consumers are informed about the health benefits of KGM will be undertaken. In the authors' opinion, cheese pies with a reduced calorie content and enhanced satiating capacity would be products that favour healthy habits without giving up a treat. These results pave the way for further strategies and developments in enhanced satiating capacity food items using KGM. Further research is needed to optimize the cheese pie formulation in terms of both preferred sensory features and the KGM dose.

ACKNOWLEDGEMENTS

The authors are grateful to the Spanish Ministry of Science and Innovation for financial support (AGL2012-36753-C02-01). They would also like to thank Mary Georgina Hardinge for assistance in correcting the English manuscript

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CAPÍTULO V

Comparison of partial and global projective mapping with consumers: A case study with satiating cheese pies

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Food Research International, 67 (2015), 323-330

ABSTRACT

In the present work the performance of global projective mapping and partial projective mapping based on texture and flavor for sensory characterization of a novel food category (satiating food product) was compared. Eight different fresh-cheese pie formulations were designed to obtain different sensory (principally texture) characteristics which could affect expected satiating perception. Three groups of consumers evaluated the samples using one of the following methodologies: global projective mapping (G-PM) (n=47), partial projective mapping based on flavor (F-PM) (n=53), and partial projective mapping based on texture (T-PM) (n=61). In addition, the expected satiating capacity of each cheese pie sample was scored on a nine-point scale. Results showed that the vocabulary used by consumers for describing the sensory characteristics of samples did not largely differ between global and partial projective mapping tasks. However, T-PM and F-PM tasks provided more detailed information than G-PM in each specific modality. Results suggested that when consumers performed the global projective mapping task they mainly took into account flavor characteristics for evaluating global similarities and differences among samples. In addition, hedonic attributes were more frequently mentioned in G-PM. Fresh cheese, sugar, corn starch and egg were the basic ingredients that conferred the fresh-cheese pies their typical, characteristic flavor and texture. The addition of whey or soy proteins, wheat bran or glucomannan increased expected satiating capacity which could be related to changes in texture (harder, more compact) leading to longer orosensory exposure. The addition of glucomannan caused the largest changes in the sensory characteristics of the cheese pies which in turn would be related to a decrease in perceived flavor intensity. Studying the interplay between formulations, sensory characteristics, expected satiating capacity and consumer liking could

Keywords: projective mapping, partial projective mapping, satiating food

1. INTRODUCTION

Interest in consumer-based sensory characterization has largely increased in the last five years, partly motivated by the need to directly include consumer input in the new product development process (Valentin, Chollet, Lelièvre, & Abdi, 2012).

Several methodologies are available for gathering information about consumers' perception of the sensory characteristics of products, being holistic methodologies one of them (Varela & Ares, 2012). These methodologies are based on the evaluation of global similarities and differences among samples, enabling assessors to decide the sensory characteristics that are responsible of perceived similarity (Ares & Varela, 2014; Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012a).

Projective mapping is one of the most popular holistic methods. It was introduced to food sensory evaluation by Risvik, McEwan, Colwill, Rogers, and Lyon (1994). In this methodology assessors are given a sheet of paper and the sample set. They are instructed to taste the samples and to place them on the sheet according to their similarities and differences, in such a way that samples that are perceived as similar should be located close to each other and samples perceived to be more different should be located further apart.

In a projective mapping task assessors should form an overall representation of the similarities and differences among samples by relying on a process of synthesis for analysing and processing sensory information (Jaeger, Wakeling, & MacFie, 2000). This process of synthesis determines the relative importance of the perceived sensory characteristics for estimating the similarities and differences among samples.

Projective mapping can present some disadvantages when specific information about a sensory modality is needed for guiding new product development since assessors would not specifically focus on it. In order to overcome this point, Pfeiffer & Gilbert (2008) proposed the application of projective mapping by modality or partial projective mapping, in which assessors are asked to evaluate similarities and differences in a specific modality (as appearance, flavor, texture) as opposed to global similarities and differences. According to these authors the partial projective mapping showed better discrimination than global projective mapping and a higher correlation with descriptive analysis. Dehlholm et al. (2012a) performed this approach to evaluate appearance, taste and mouthfeel of commercial samples of liver pâté. This sensory technique has also been used to compare the response of consumers when they just looked at the packaging (like in a supermarket) or tasted the sample (having or not the information from the packaging) (Carrilo, Varela & Fiszman, 2012).

Food products with enhanced satiating capacity could be considered as a new category of food. Satiating products used as between-meal snacks can produce consumer satisfaction at a particular time, because of their filling effects, and encourage healthy dietary habits when used as a way to prevent weight gain (Tárrega, Martínez, Vélez-Ruiz, & Fiszman, 2014). There is a need for formulating healthier low-energy, low-fat products that are affordable, attractive, convenient and, importantly, as tasty and gratifying as those they are intended to replace (Halford & Harrold, 2012).
It has been observed that the sensory properties of this product category, particularly texture, play a role in expected satiating capacity (how filling a food is likely to be and to what extent it is likely to stave off hunger until the next meal) (Hogenkamp, Stafleu, Mars, Brunstrom, & de Graaf, 2011;

Yeomans & Chambers, 2011). Since orosensory exposure is a fundamental step for elicitation of pre-absorptive satiating-related signals the in-mouth sensory perception and characterization become an essential point in development of satiating food. According to Yeomans, McCrickerd, Brunstrom, and Chambers (2014) there was stronger evidence of learned satiety when drink's textural (viscosity) rather than flavor cues predicted nutrient content, perhaps because texture is a more consistent predictor of energy: low satiation/satiety response of beverages can be largely attributed to their shorter oral residence time than solid food (De Graaf, 2012).

Texture characteristics can be overlooked by consumers when they evaluate some product categories (Szczesniak, 2002). Therefore, global projective mapping could potentially miss to identify similarities and differences in this specific sensory modality, which could be highly relevant for the development of satiating foods. For this reason, having a consumer insight into the texture features of new designed satiating food products through partial projective mapping would be highly convenient.

The aim of the present work was to compare the performance of global projective mapping and partial projective mapping based on texture and flavor for sensory characterization of novel satiating fresh-cheese pies with different texture characteristics. In addition, the correlation between the expected satiating capacity scores and the sensory characteristics of the samples were analysed.

2. MATERIALS AND METHODS

2.1. Samples

Fresh-cheese pie is a refrigerated dairy dessert that is basically made of fresh cheese, eggs, sugar, milk, and starch. It differs from American cheesecake in not having a crust and having a soft, spongy, moist, gel-like texture which can be cut with a knife. Fresh cheese is made from pasteurized non-cultured cows' milk and is characterized by a creamy, firm texture with a mild milky flavor. Eight different fresh-cheese formulations were designed (Table 1) to obtain different sensory textures which could affect expected satiating capacity perception. None of the formulation changes distorted the nature of the sample pies.

Three samples were formulated by removing one of the minor ingredients from the basic recipe (B): no egg (B-E), no corn starch (B-CS), or no sugar (B-S) to obtain different textures. In sample B-S a high-intensity sweetener was added to compensate sweetness changes. Considering that high protein content is related to higher satiating capacity, two samples were formulated by adding a higher level of protein: soy protein (B+SP) and whey protein (B+WP). The last two samples were formulated by adding fibre ingredients which could add satiating capacity by different mechanisms: wheat bran (B+WB), or konjac glucomannan (B+K).

Table 1. Formulation of cheese pie samples

Ingredients	Sample*							
	B	**B-E**	**B-S**	**B-CS**	**B+SP**	**B+WP**	**B+WB**	**B+K**
Fresh cheese	55.00	68.75	61.11	57.89	52.80	52.80	53.90	56.59
Whole egg	20.00	-	22.22	21.05	19.20	19.20	19.60	20.58
Sugar	10.00	12.50	-	10.53	9.60	9.60	9.80	10.29
Skimmed milk	10.00	12.50	10.28	10.53	9.60	9.60	9.80	10.29
Corn starch	5.00	6.25	5.56	-	4.80	4.80	4.90	-
Whey protein	-	-	-	-	-	4.00	-	-
Soy protein	-	-	-	-	4.00	-	-	-
Wheat bran	-	-	-	-	-	-	2.00	-
Konjac glucomannan	-	-	-	-	-	-	-	2.25
Sweetener	-	-	0.83	-	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*** B**: Basic formulation, **B-E**: without whole egg, **B-S**: without sugar, **B-CS**: without corn starch, **B+SP**: soy protein added, **B+WP**: whey protein added, **B+WB:** wheat bran added, **B+K**: konjac glucomannan added

2.1.1 Ingredients

The ingredients used in the formulation of the eight fresh-cheese pies were: full-fat fresh cheese (starter-free, pasteurized, protein content 10.9 g/100g, moisture 72 g/100g and fat 14 g/100g as declared by the supplier, Hacendado, Spain), pasteurized liquid whole egg (Ovocity, Valencia, Spain), sucrose (Acor, Valladolid, Spain), maize starch (Maizena®, Barcelona, Spain), skimmed milk powder (Central Lechera Asturiana, Siero, Spain), whey protein isolate (WPI, Best Protein®, 90 g/100g protein content, Barcelona, Spain), wheat bran (Harinera Castellana, Valladolid, Spain) and konjak glucomannan (Trades S.A, Barcelona, Spain).

2.1.2. Sample preparation

2.1.2.1. Batter preparation

The basic recipe batter was prepared in a mixer (Kenwood Major Classic, UK), at top speed (580 rpm). Firstly, the cheese was whisked for 1 min, and then the egg and sugar were added separately and mixed in for 1 min more after each addition. The milk powder was dissolved in water and the starch dispersed in it. These were added to the mixture, which was beaten for a further 1 min. Lastly, any other ingredient (if any) was added and the final mixture was beaten for 16 min. A total of 20 min processing was used for all formulations.

2.1.2.2. Baking

The batter was poured into a heat-resistant silicone mould for five rounded pies (7 cm in diameter and 3.5 cm in height) and baked for 25 min at 180°C in an electric oven (De Dietrich, Basingstoke, UK), preheated for 15 min. The oven, the tray and the tray position in the oven were identical in each case. The pies were left to cool at room temperature for 1 h, then demolded and stored under refrigeration (4 °C) for 24 h before the sensory tests were carried out.

2.2. Consumer perception of the cheese pies

2.2.1. Consumers

A total of 161 consumers participated in the study. Consumers were aged between 18 and 64 (average age was 29.6, SD= 10.2), being 59% female recruited from Polytechnic University of Valencia staff and students. Participants were recruited based on their consumption of cheese pie (at least occasionally), their interest and availability to participate in the study. Consumers were given a small gift for their participation.

The consumer study was carried out in three separate sessions. In each of the sessions different groups of participants evaluated the samples using a different methodology: global projective mapping (G-PM), partial projective mapping based on flavor (F-PM) and partial projective mapping based on texture (T-PM). The number of participants who participated in each of the sessions was 47, 53 and 61 respectively. Participants were not explained about the specific aim of the study and did not receive any training prior to the assessment. According with Vidal, Cadena, Antúnez, Giménez, Varela, & Ares (2014) although the stability of sample configuration in projective mapping tests clearly depend on the degree of difference and type of differences among samples, 50 consumers seems a safe and conservative recommendation in most situations.

2.2.2. Experimental procedure

The pies were cut into six pieces (wedge shape); the 8 samples (one piece of each cheese pie) were presented all together in a round plastic plate, in random order. Samples were coded with 3-digit random numbers and were identified using small pieces of paper with re-adhereable strip of glue on their back. Consumers were provided with pen, a sheet of paper (DIN A3) and were instructed to try the samples and to place them in the sheet of paper according to their similarities and differences, using the small pieces of paper with the 3-digit codes. They were explained that samples that were considered similar should be placed near each other, while samples perceived as different should be located far from each other. Consumers who completed the global projective mapping (G-PM) were asked to locate samples according to their global similarities and differences, while participants who performed the partial projective mapping task were asked to focus on the specific modality: similarities and differences in flavor (F-PM) or texture (T-PM). All participants were instructed to use the entire sheet surface. They were free to taste the samples in any order and to try them as many times as they wanted. After placing the samples in the sheet of paper consumers had to write down the terms that described each sample (Perrin, Symoneaux, Maître, Asselin, Jourjon, & Pagès, 2008). They had no time limit to complete the task. Consumers needed between 10 and 25 minutes to complete the projective mapping task.

After completing the projective mapping task the consumers scored the expected satiating capacity of each cheese pie sample on a nine-point scale, from 1=”If I ate this whole pie it would not fill me at all” to 9 =”If I ate this whole pie it would fill me a lot” (as the pies were cut into six wedge pieces it was easy to figure out the size of the whole pie).

All the assessments were carried out in sensory booths, designed in accordance with ISO 8589 (ISO, 2007), under artificial daylight and temperature control (22°C). Still mineral water was available for rinsing between samples but it was not enforced.

2.3. Data analysis

Data from each projective mapping tasks were analysed using Multiple Factor Analysis (MFA). The abscissa (X) and ordinate (Y) values of each sample on the sheet of paper of each consumer were determined considering the left bottom corner of the sheet as the origin of coordinates. MFA was performed considering the coordinates of each consumer as a separate group of variables (Pagès, 2005). Confidence ellipses for a 95% confidence level were constructed using parametric bootstrapping (Dehlholm, Brockhoff, & Bredie, 2012b).

The words elicited by consumers in the description phase were qualitatively analyzed by two independent researchers. Words with similar meaning were grouped into categories by two independent researchers. After individual evaluation of the words a meeting of the two researchers was held to determine the final categories. The frequency of mention of each category for describing each of the samples was determined. Terms mentioned by at least 5% of the consumers were retained for further analysis (Symoneaux, Galmarini, & Mehinagic, 2012). The frequency table was considered as a group of supplementary variables in the MFA (Pagès, 2005).

Sample configurations in the first four dimensions of each projective mapping task were compared using the RV coefficient. This coefficient depends on the relative position of the points in the configuration and therefore is independent of rotation and translation (Robert & Escoufier,

1976). It takes the value of 0 if the configurations are uncorrelated and the value of 1 if the configurations are homothetic. A permutation test was used to evaluate the significance of the RV coefficient (Josse, Pagés, & Husson, 2008).
These statistical analyses were performed using the FactoMineR package (Lê, Josse, & Husson, 2008) in R language (R Core Team, 2013).

Analysis of variance (ANOVA) was performed on expected satiating scores of the different cheese pie samples considering sample as fixed effect and consumer as random effect. Tukey's test was applied to evaluate the statistical differences between the means (α= 0.05). This analysis was performed with Statgraphics Centurion XVI (Warrenton, Virginia, USA).

3. RESULTS AND DISCUSSIONS

3.1. Partial projective mapping based on texture

The first and second dimensions of the MFA explained 49.87% of the variance of the experimental data. As shown in Figure 1(a) sample B-CS was located at negative values of the first dimension. This sample was characterized by its *Soft, Moist* and *Spongy* texture (Figure 1 c), in agreement with the fact that it was formulated without starch, which is act as a moisture retention agent and thickening agent. Samples B-S and B were located a little far apart from sample B-CS but were also located at negative values of the first dimension with their confidence ellipses almost completely overlapped. As shown in Figures 1 a and 1 c the texture of these two samples was described as *Creamy, Homogeneous, Light, Easy to chew* and *Good,* which corresponded to the typical characteristics of this type of pie.

Samples B+WP, B+SP and B-E formed a quite close group indicating that their texture was perceived as similar by consumers, although their confidence ellipses did not completely overlapped. This three samples were characterized by their *Hard, Dry, Compact, Astringent, Sandy* and *Difficult to chew* texture (Figures 1 a and c). These characteristics are in agreement with these samples' formulation. Egg contributes extra moisture and fat to the formulation and possesses emulsifying effects, so it might be expected that sample B-E, formulated by removing egg from the basic formulation, would be perceived as dry and hard. Samples B+WP and B+SP had added proteins (contributing more solids) which lead to harder, drier and more compact pies compared to the basic formulation (B).

Sample B+WB occupied a distinct position in the sample configuration, suggesting that it was perceived as very different from the rest. This sample was located at negative values of the second dimension of the MFA and was described as *Grainy, Fibrous* and with an *Unpleasant texture*, suggesting that the addition of wheat bran was clearly detected by the consumers who perceived this sample as having distinct characteristics.

Finally, sample B+K was located at a central position in the representation of the first and second dimensions (Figure 1a) but it was clearly differentiated from the rest in the third dimension (Figure 1b). This sample showed a distinct texture, described as *Pasty*, *Greasy* and *Gummy* (Figure 1d), which could be explained by the addition of glucomannan, a thickener that absorbs large amounts of water.

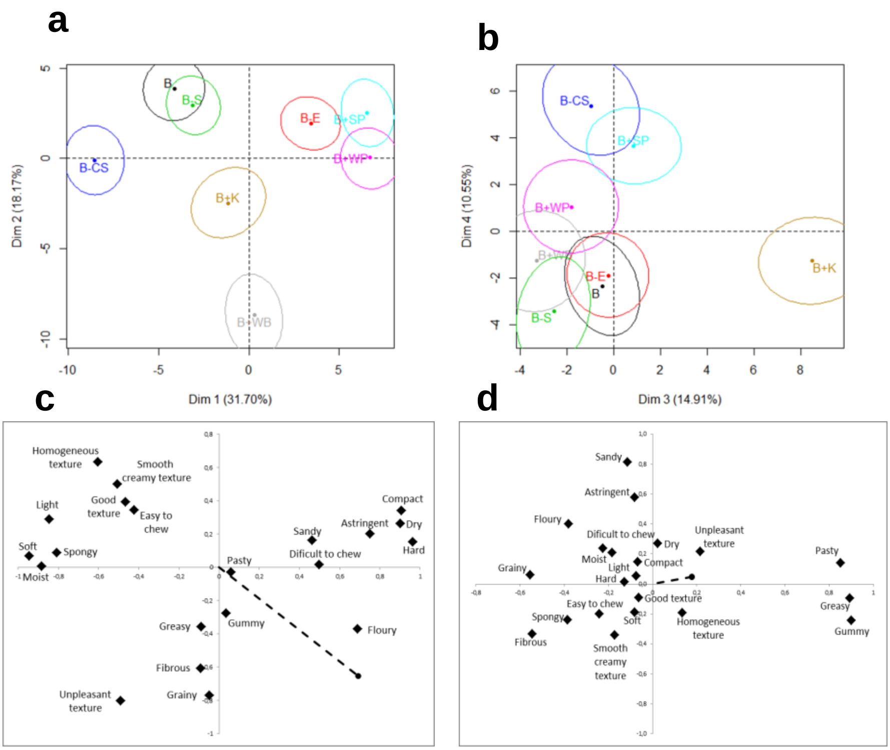

Figure 1. Results of the Multiple Factor Analysis performed on data from the partial projective mapping based on texture. Representation of the cheese pie samples (a) in the first and second dimensions, and (b) in the third and fourth dimensions, and projection of the terms (c) in the first and second dimensions, and (d) in the third and fourth dimensions

3.2. Partial projective mapping based on flavor

Three main groups of samples were identified in the first and second dimensions of the MFA of data from the partial projective mapping based on flavor (Figure 2a). One of the groups was located at negative values of the first dimension and was composed of samples B, B-E, B-CS, and B-S, being the confidence ellipses of the first two samples completely overlapped. All these samples shared the typical flavor features of fresh-cheese pies *Dairy*, *Cheese*, *Intense, Balanced*, *Sweet*, and *No aftertaste* (Figure 2c). However, sample B-CS was sorted apart from the rest in the third and fourth dimensions of the MFA (Figure 2c), mainly by its higher intensity of other tastes that were not characteristic of the traditional cheese pie (sample B) such as *Egg taste, Vegetal taste* or coconut, vanilla, caramel, honey, nuts (walnut, almond, hazelnut) all these grouped as *Other non-characteristic flavor* (Figure 2d).

A second group of samples was located at positive values of the first dimension and was composed of samples B+WB, B+WP and B+SP, with their confidence ellipses somewhat overlapped (Figure 2a). These three samples were associated to a series of off- flavors which are not expected in a fresh-cheese pie: *Floury*, *Vegetal*, *No cheese taste*, *Slightly sweet*, *Astringent* or *Unpleasant taste* (Figure 2c). These three samples were formulated with the addition of different types of proteins and wheat bran to increase satiating capacity. Samples B+WB and B+SP were clearly differentiated in the third and fourth dimensions of the MFA (Figure 2b). Sample B+SP (formulated with the addition of soy protein) was associated with the terms *Off- flavor, Astringent* and *Unpleasant taste; m*eanwhile, sample B+WB, formulated with wheat bran was associated with the terms *Not characteristic flavor* and *Light taste* but it was not described with terms related to off- flavors (Figure 2d).

Finally, sample B+K was isolated from the rest in the bottom-right part of the map and was associated with the terms *No cheese taste*, *Tasteless* and *Unpleasant taste*. This sample was formulated with glucomannan and had a pasty ad gummy texture (Figure 1), which could have affected in-mouth flavor release.

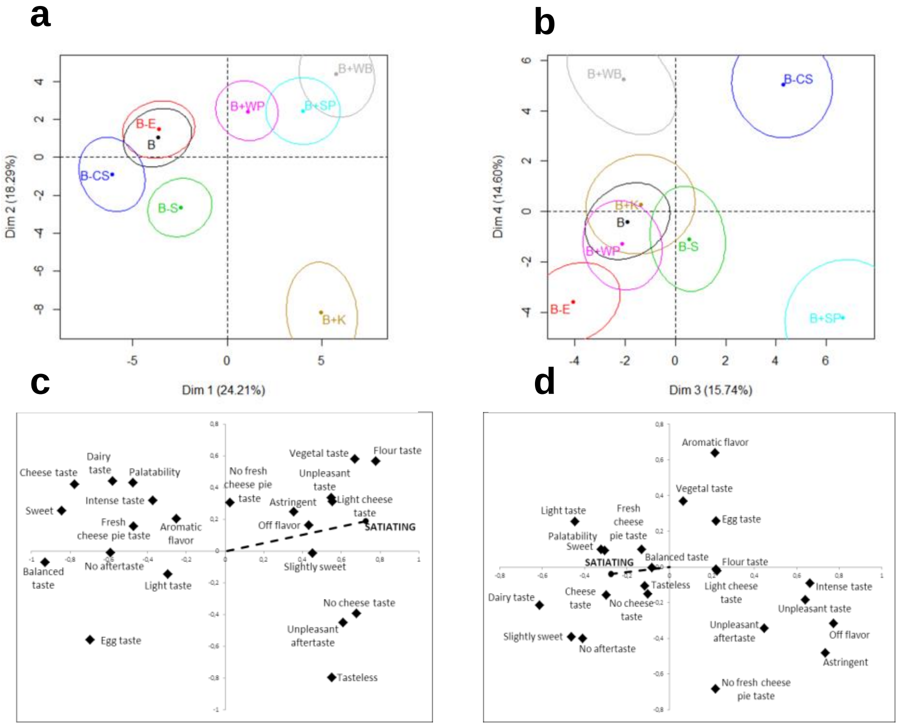

Figure 2. Results of the Multiple Factor Analysis performed on data from the partial projective mapping based on flavor. Representation of the cheese pie samples (a) in the first and second dimensions, and (b) in the third and fourth dimensions, and projection of the terms (c) in the first and second dimensions, and (d) in the third and fourth dimensions

3.3. Global projective mapping

As shown in Figure 3a samples B+WP, B+SP, and B+WB appeared as one group with their confidence ellipses almost completely overlapped. This group of samples was located at positive values of the first and second dimensions and was described as having *Hard*, *Dry*, *Compact*, *Sandy*, *Grainy*, *Floury, Difficult to chew*, and *With fibre particles* texture characteristics and *Off- flavor, Unpleasant aftertaste*, and *Vegetal taste*

(Figure 3c) characteristics. Sample B+WP had a distinct position in the third and fourth dimensions of the MFA (Figure 3b) due to its *With fiber particles* texture, *No cheese taste* and *Vegetable taste* (Figure 3d)

Samples B-S, B-E, B, and B-CS were distributed along negative values of the first dimension of the MFA (Figure 3a). These samples were described with the taste terms *Sweet*, *Cheese taste*, *Pleasant taste*, *Dairy taste* and *Fresh-cheese pie taste*, and with the texture terms *Good texture*, *Smooth/ creamy*, *Soft*, *Moist*, *Spongy*, *Fondant*, *Good dessert* (Figure 3c). All these characteristics are typical of conventional, well-known cheese pie. Sample B-CS was sorted apart in the third and fourth dimensions of the MFA (Figure 3b) due to its *Intense, Egg taste* and *Fondant* (Figure 3d).

Finally, sample B+K was isolated from the rest and was located at negative values of the second dimension and positive values of the first dimension. This sample was described as having *Greasy*, *Mouth coating*, *Gummy*, *Pasty* and *Unpleasant* texture, *Tasteless*, with *No fresh-cheese pie taste* flavor and as an *Unpleasant dessert*.

The first dimension of the MFA clearly opposed samples with the “appropriate”, expected characteristics of cheese pie (the typical, basic formulation and samples produced by removing one minor ingredient) from those having unsuitable or unexpected sensory characteristics (formulated by the addition of extra ingredients to improve expected satiating capacity). This could be related to an underlying influence of consumers' preferences on the position of the samples along the first dimension of the MFA, positioning the known, “familiar” samples opposed to new, unfamiliar ones. It was quite clear that a very relevant role in determining the opposite positions of the samples was played by the descriptors related to the liking, such as *Unpleasant Dessert*, *Unpleasant texture*, and *Unpleasant taste* (positively correlated to first dimension) and *Good dessert* and *Good* *texture* (negatively correlated to first dimension). Since consumers were required to place the samples in the sheet of paper according to their similarities and differences (without any other more precise predefined criterion), it seems that their decisions were influenced by their liking for samples. These results are in good agreement to Torri, Dinnella, Recchia, Naes, Tuorila, & Monteleone (2013) who stated that liking could be considered as the main criterion for the evaluation of similarities and dissimilarities in the aroma of wine samples by consumers.

As shown in Figure 3, expected satiating capacity scores were correlated with the first and second dimension, particularly with texture terms such as *Compact*, *Hard* and *Pasty*, in agreement with the fact that samples formulated with the addition of proteins, bran or hydrocolloids showed the significantly highest expected satiating capacity (c.f. Table 2). This relationship can be explained considering that harder, drier textures of food products elicit higher satiating expectations than *soft*, *fondant,* or *creamy* ones due to increased oral activity required to chew the product and to form a ready-to-swallow bolus. It is documented that energy delivered in liquid form elicited weaker physiological responses associated with satiety than solid food. Evidence exists for differences between solids and beverages in terms of cognitive effects, oral processing, or gastric empting time, among other factors (Tucker & Mattes, 2013). One explanation for such differences is that information present at the time of consumption generates expectations that modulate post-ingestive (actual) satiety processes, and the overall experience of satiety reflects this integration of cognitive, sensory and nutrient-induced cues (Yeomans, et al., 2014).

Expected satiating capacity was also correlated with flavor terms, such as *Off- flavor, Slightly sweet*, and *Flour taste.* However, these sensory characteristics were not the responsible for satiating power elicitation and were correlated to expected satiating capacity scores because their association with the ingredients which increase expected satiating capacity.

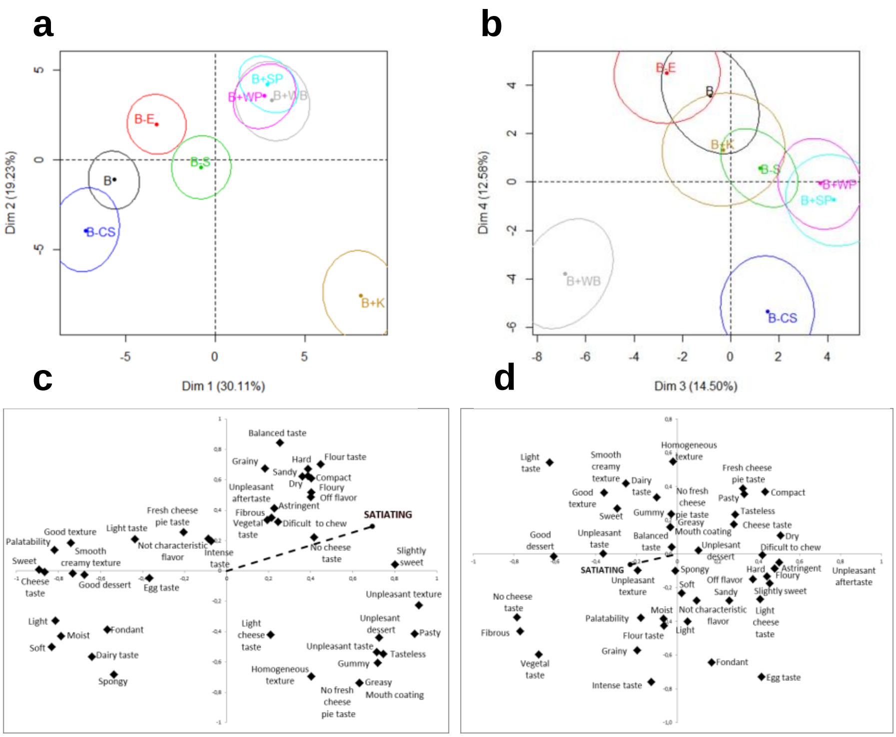

Figure 3. Results of the Multiple Factor Analysis performed on data from the global projective mapping task. Representation of the cheese pie samples (a) in the first and second dimensions, and (b) in the third and fourth dimensions, and projection of the terms (c) in the first and second dimensions, and (d) in the third and fourth dimensions

Table 2. Average values of consumers' expected satiation scores for cheese pie samples

	Sample *							
	B	B-E	B-S	B-CS	B+SP	B+WP	B+WB	B+K
Expected satiation[1]	5.5^{a}	6.6^{b}	5.3^{a}	5.7^{ab}	6.5^{b}	6.9^{bc}	7.0^{c}	6.8^{bc}

* The description of the samples is provided in Table 1.
[1] Values obtained on a 9-point scale. Average values with different superscripts are significantly different according to Tukey's test for a significance level of 0.05

3.4. Comparison of global and partial projective mapping tasks

Consumers were able to perform partial projective mapping tasks and they did not report any problem. The words provided to describe samples were only related to the specific modality considered in the task, suggesting that they focused their attention on the specific modality considered in the task. It is worth noting that the term *Astringency* was mentioned in the two partial projective mapping tasks, indicating that some consumers perceived this sensation but they were not able to classify it as a flavor or a texture characteristic. Astringency has been shown to be a multiple perceptual phenomenon associates to the terms drying, puckering, sour, bitter and rough (Gawel, Iland, & Francis, 2001). Astringency perception in the cheese pies added with proteins can be explained considering that high protein dairy beverages are usually perceived as mouth drying, although the mechanism of this mouth drying is uncertain (Withers, Cook, Methven, Gosney, & Khutoryanskiy, 2013).

The vocabulary used by consumers for describing the sensory characteristics of samples within a specific modality did not largely differ between the global and partial projective mapping tasks. In addition, hedonic attributes' mention was more evident in global modality; this could be attributed to participants considered global modality as a more open-minded situation where preference opinions could be valid, whereas partial modality could be considered more restricted and with a narrower focus.

As shown in Table 3, the number of categories was higher for the global projective mapping task than for the partial ones due to the fact that in the latter consumers described all the characteristics of the samples. However, the number of categories within each modality in which consumers' descriptions could be grouped were similar for both types of tasks. This suggested that consumers were stable in the way they described the samples, even if relying on different aspects of the samples to evaluate similarities and differences among them. Basically, the categories identified in the analysis were similar, although they were some exceptions. For example, the terms *Citric, Wheat taste, No aftertaste* were identified in the partial projective mapping based on flavor while they were not mentioned in the global projective mapping, whereas the opposite trend was found for the term *Vanilla*. Meanwhile, the only differences between global projective mapping and partial projective mapping based on texture was related to the terms *Fondant* and *Easy to chew*. The first one was only mentioned in the global projective mapping, whereas the second one was only identified in the partial projective mapping based on texture.

Table 3. Number of categories within each modality identified in the description phase of global (G-PM) and partial projective mapping based on texture (T-PM) and flavor (F-PM)

Methodology	Texture	flavor	Hedonic	Total number of categories
G-PM	20	27	7	54
T-PM	20	0	2	22
F-PM	1 (*)	30	3	34

(*) The only texture category identified in the projective mapping based on flavor was astringency

Differences in sample configurations from partial projective mapping tasks (based on texture and flavor) and the global one were identified. As shown in Table 4, the most similar sample configurations were those from global projective mapping and partial projective mapping based on flavor. As shown in Figures 2 and 3 sample configurations from global projective mapping and partial projective mapping based on flavor were highly similar. The main difference was related to the overlapping of the confidence ellipses and the position of sample B+SP in the third and fourth dimensions of the MFA. These results suggested that when consumers spontaneously evaluated global similarities and differences among samples, flavor characteristics were more salient for making distinctions among samples than texture characteristics. According to Szczesniak (2002) for most products, texture is taken for granted and consumers do not comment on it unless texture defects are perceived, or expectations are not fulfilled. This was probably the case for sample B+WB in which visible particles of wheat bran were found abnormal in a cheese pie. Similarly, sample B+K was perceived clearly different from the rest in both partial projective mapping tasks, probably because of its gummy texture. Gummy textures or those that contain lumps or hard particles are usually rejected because people like to be in full control of the food they place in their mouth (Szczesniack , 2002).

Table 4. RV coefficient between sample configurations in the first four dimensions of the Multiple Factor Analysis performed on data from global (G-PM) and partial projective mapping based on texture (T-PM) and flavor (F-PM)

Methodology	G-PM	T-PM	F-PM
G-PM	1	-	-
T-PM	0.877***	1	-
F-PM	0.791**	0.759**	1

**indicates that the RV coefficient is significant at p<0.01; ***indicates that the RV coefficient is significant at p<0.001

It is interesting to note that some of the conclusions regarding texture similarities and differences among samples were not observed in the global projective mapping. For example, samples B and B-S did not differ in their texture since their confidence ellipses were overlapped in the first four dimensions of the MFA (Figure 1), while in global projective mapping they were perceived as different (Figure 3). On the contrary, samples B+WP and B+SP showed clearly different texture characteristics but were perceived as similar in the global projective mapping (c.f. Figures 1 and 3)
Conclusions regarding similarities and differences among samples differed between the different projective mapping tasks. In some cases partial projective mapping tended to show more discrimination than global projective mapping for some of the samples. For example, in global projective mapping the confidence ellipses of samples B+SP, B+WP and B+WB were completely overlapped, indicating that they shared their most important texture and flavor characteristics. However, in partial projective mapping based on flavor these three samples presented only some degree of overlapping. Therefore, it seems that by focusing on flavor characteristics consumers were able to find more distinctive characteristics among these samples. Since texture attributes demonstrated to be more related to elicitation of expected satiating capacity, these three samples would be apt for designing enhanced satiating food whereas taste should to be more finally tuned to be acceptable.

On the other hand, there were other cases in which only one of the partial projective mapping tasks was not able to spot the sensory differences identified in global projective mapping. For example, the confidence ellipses of samples B and B-E were completely overlapped in partial projective mapping based on flavor (Figure 2), while global projective mapping was able to separate them (Figure 3), indicating that they did not share texture characteristics (Figure 1).

4. CONCLUSIONS

Consumers were able to complete partial projective mapping tasks, focusing on a specific modality to estimate the degree of difference among samples. Partial projective mapping tasks provided information that was not gathered in the global projective mapping, particularly regarding differences among samples in specific modalities. This suggests that an evaluation with a narrower focus could be positive for consumers' discriminative ability when performing the projective mapping as they concentrate their efforts on the specific modality. Global projective mapping showed the highest RV coefficient with partial projective mapping based on flavor, suggesting that flavor attributes were the main drivers of consumers' perceived global similarities and differences among samples or at least they were easier to compare than texture features. These results suggested that partial projective mapping can be an interesting tool for exploring consumers' perception when information about specific sensory modalities is needed, particularly when working with novel food categories.

Regarding the sensory characteristics of the cheese pies, fresh cheese, sugar, corn starch and egg were the basic ingredients that conferred the pies their typical, characteristic flavor and texture. Addition of whey or soy proteins, wheat bran or glucomannan which led to an increase in expected satiating capacity caused remarkable changes, setting them apart from their typical sensory characteristics. Texture characteristics such as hardness and dryness were correlated with higher expected satiating capacity, which could be related to the fact that these textures are more laborious to handle in the mouth and lead to longer orosensory exposure. The addition of glucomannan to the cheese pies caused the largest changes in the sensory characteristics of the cheese pies due to its harder and more compact texture, which was also related to a decrease in perceived flavor intensity.

Studying the interplay between formulations, sensory characteristics, expected satiating capacity and consumer liking could largely contribute to the development of this novel food category.

ACKNOWLEDGEMENTS

The authors are grateful to the Spanish Ministry of Economy and Competitiveness for financial support (AGL2012-36753-C02-01) and to the Comisión Sectorial de Investigación Científica (Universidad de la República, Uruguay).

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DISCUSIÓN

La matriz alimentaria elegida como modelo para el estudio fue un pastel de queso fresco de bajo contenido calórico y alto contenido proteico. Éste podría consumirse como postre o como tentempié, generando altas expectativas hedónicas en los consumidores; a la vez les aportaría efectos saciantes beneficiosos para la salud, relacionados con el control de peso y tratamiento de la obesidad.

La variedad de ingredientes aportó gran versatilidad para realizar reformulaciones sin distorsionar las características estructurales y sensoriales inherentes a la formulación básica y que determinan su aceptabilidad. Estas reformulaciones se realizaron de acuerdo a las diferentes estrategias que se abordaron en la presente memoria para diseñar un producto saciante.

Dichas estrategias abarcaron distintos estudios en relación con la generación de expectativas de la capacidad saciante y la creación de viscosidad en el antro gástrico: características del pastel después de la eliminación o adición de alguno de los ingredientes minoritarios, la adición de nuevos ingredientes con alto poder saciante, como proteínas lácteas (aislado proteico de suero lácteo), proteínas vegetales (concentrado de proteína de soja) o glucomanano de konjac y el aumento de la complejidad tanto visual como de textura (incorporación de copos de avena, salvado de trigo, semillas de lino o coco rallado).

FASE PREINGESTIVA. ASPECTOS SENSORIALES Y COGNITIVOS

La textura y características finales de los pasteles de queso dependen principalmente de su composición. La presencia de una compleja variedad de ingredientes dificulta conocer qué cambios pueden esperarse durante su reformulación, ya que se presentan múltiples interacciones.

La **hipótesis de partida** en el capítulo I fue que la realización de cambios en la formulación básica de los pasteles de queso, **eliminando totalmente o aumentando la cantidad de alguno de sus ingredientes minoritarios** (huevo, azúcar, leche o almidón de maíz), podría generar cambios en la dinámica de la trayectoria oral durante el consumo, que a su vez podría tener influencia sobre la generación de expectativas de la capacidad saciante.

En las pruebas de predominio temporal de las sensaciones (TDS), las muestras sin huevo y con leche añadida se diferenciaron claramente del resto, fueron predominantemente duras y secas durante el tiempo de consumo y requirieron un procesamiento oral más prolongado. Esto demostró las funciones del huevo dentro de la formula básica como estabilizador de la textura y de las proteínas lácteas como agentes generadores de estructura. La muestra control fue predominantemente blanda y cremosa durante la mayor parte del tiempo de consumo, mientras que en la muestra sin azúcar el predominio de la cremosidad se redujo, lo que indicó que el azúcar, adicionalmente a su aporte al sabor, funciona como agente estabilizador durante el batido de las mezclas. Las muestras con nata añadida y las que no llevan almidón de maíz fueron blandas, cremosas y predominantemente más húmedas que el resto, debido, respectivamente, al aporte extra de agua disponible proporcionado por la nata o a la ausencia de las funciones de retención de humedad del almidón.

Estos resultados sobre la trayectoria oral se alinearon con los valores de capacidad saciante esperada y de dureza instrumental obtenidos. Las muestras sin huevo y con leche añadida fueron las de mayor dureza instrumental y mayor capacidad saciante, seguidas de las muestras control y sin azúcar. En el otro extremo, como las menos saciantes, se encontraron las muestras sin almidón de maíz y con nata.

La aceptabilidad dinámica mostró que a medida que transcurrió el tiempo de exposición oral, se incrementaron gradualmente los valores de aceptabilidad, lo que resaltó la importancia de su estudio, aunque la aceptación global (estática) parece estar más relacionada con el primer impacto en boca. La combinación de estos resultados con el análisis de penalización de los atributos clave (que indica cuánto se distancian de su nivel ideal según los consumidores) contribuyó a conocer el intervalo en que se puede mover la textura garantizando la obtención de resultados hedónicos aprobables.

La hipótesis de partida planteada en el Capítulo II fue que la **incorporación de cantidades extra de proteína**, dado que es el macronutriente con mayor capacidad saciante, podría provocar diferencias en las expectativas de capacidad saciante, además de alterar otras características de los pasteles de queso.

El uso de concentrado de proteína de soja debido a su alta capacidad espesante, permitió disminuir el porcentaje de grasa (mayor proporción de queso fresco desnatado) respecto de las formulaciones control, conservando un comportamiento viscoelástico similar en las mezclas batidas antes del horneado; la adición de proteína de suero lácteo, provocaron un aumento de los valores medios de los módulos viscoelásticos, que se tradujo en la formación de estructura más fuertes tipo gel, como resultado de las interacciones proteína-proteína. Los valores medios de dureza y masticabilidad instrumentales de los pasteles también aumentaron con el incremento en el contenido de ambos tipos de proteína debido a su desnaturalización durante el horneado, promoviendo una mayor retención de agua y compactación de la estructura total. Las muestras con proteína de suero lácteo, debido a su especial habilidad para formar matrices más compactas, fueron más duras que las muestras con proteína de soja.

Estos resultados se relacionaron perfectamente con los obtenidos en el cuestionario C.A.T.A. aplicado como herramienta para conocer el perfil sensorial definido por los consumidores. Las muestras con mayor contenido en proteína añadido se describieron con atributos tales como "duro", "compacto" y "seco" (particularmente altas para la muestra con mayor contenido en proteína láctea), "denso", "harinoso" y "arenoso". En el otro extremo, las muestras control, independientemente de su contenido en grasa, se asociaron a términos como "suave", "cremoso", "blando", "ligero", "húmedo", "fondant" y "esponjoso". Esto sugirió que las muestras con proteína añadida fueron más consistentes y difíciles de masticar. Respecto del sabor, las muestras con proteína láctea añadida junto con las muestras control estuvieron asociadas a los términos de sabor "esperados" en un pastel de queso ("dulce", "sabor a queso" y "sabor a leche"); mientras que las muestras con proteína de soja añadida se asociaron a términos de sabor probablemente "no esperados" como "extraño", "astringente", "sabor a soja", "sabor a harina" o "sabor a almidón".

En cuanto a la capacidad saciante percibida, la muestra correspondiente a la formulación con mayor contenido de proteínas de suero lácteo añadido obtuvo un valor medio significativamente mayor que el resto de las muestras, las cuales no se diferenciaron significativamente entre sí. Este resultado se atribuye a que mayores resistencia a la masticación y tiempo de procesamiento oral contribuirían a relacionar dicha textura con un alimento de composición más "rica en nutrientes" y en consecuencia, más saciante. Es posible que las muestras con alto contenido de proteína de soja no obtuvieran valores altos en expectativas saciantes, debido a las características "no deseadas" de sabor ya comentadas, que al no resultar familiares, rebajan las expectativas de consumo en general.

En los capítulos I y II de la presente memoria se evidenció que las características de textura, tanto por variación de los ingredientes minoritarios como por la adición de proteínas, gobiernan las expectativas de saciedad de los consumidores.

En el capítulo III se buscó la relación entre la percepción de complejidad y las expectativas de capacidad saciante. La **hipótesis de partida** fue que pasteles de queso con similar dureza instrumental, pero con **una mayor complejidad** (relacionada con su dificultad para el procesamiento oral) por la presencia de partículas visibles, conducirían a la apreciación de diferencias en su percepción de capacidad saciante.

Se reformularon pasteles de queso incorporándoles diferentes ingredientes con distintas propiedades físicas y tamaño de partícula: salvado de trigo, copos de avena, semillas de lino y coco rallado. También se formuló una muestra control (sin adición de partículas) y una última muestra (sin adición de partículas y con nata de leche). La muestra con copos de avena presentó los mayores valores para fuerza máxima de penetración y dureza (TPA) instrumentales, mientras que los valores de las muestras con salvado de trigo, semillas de lino y coco rallado no presentaron diferencias significativas entre sí, siendo mayores que los de las muestras control, y estos a su vez mayores que los de la muestra con nata de leche, que resultó ser la más blanda y menos resistente a la deformación.

En cuanto a su complejidad, la muestra con salvado de trigo se percibió como la más compleja, seguida de la muestra con semillas de lino, ambas con partículas de color oscuro y tamaño bien visible. Por su parte, las muestras con copos de avena y coco rallado fueron menos complejas que las anteriores y sin diferencias significativas entre sí, posiblemente debido a que sus partículas eran blancas y se encontraban bien integradas en la masa del pastel, principalmente el coco con menor tamaño de partícula. Las muestras control y con nata añadida (sin presencia de partículas) fueron percibidas como las menos complejas.

En cuanto a la capacidad saciante, la muestra con copos de avena obtuvo el mayor valor medio y la muestra con nata añadida el menor, lo cual se encuentra perfectamente alineado con los resultados de textura instrumental y sugirió que la textura hizo una gran contribución a las expectativas de capacidad saciante.

Sin embargo lo destacable de este estudio es que entre las muestras sin diferencia significativa en sus atributos de textura instrumental, a mayor percepción de complejidad, se obtuvieron mayores valores de capacidad saciante esperada. La muestra con salvado de trigo (la más compleja) obtuvo el mayor valor, seguida de la muestra con semillas de lino y por último la muestra con coco rallado como la menos saciante (la calificada como menos compleja). La presencia de partículas grandes o semillas probablemente incrementó los valores de complejidad de estas muestras no sólo por su apariencia no homogénea sino también debido a la masticación más compleja que requieren. En cuanto a los términos asociados a la complejidad que generaron los participantes, los más mencionados fueron “textura”, “homogeneidad” y los referidos a la presencia de partículas: “apariencia”, “presencia”, “componente”, “diferente” y “cantidad”; lo cual indicó que la textura y las características de las partículas añadidas fueron los aspectos que más tuvieron en cuenta para estimar la complejidad de las muestras.

FASE POSTINGESTIVA. DISTENSIÓN - VACIADO GÁSTRICO Y SACIEDAD

El glucomanano de konjac es una fibra soluble con alta capacidad para producir viscosidad en soluciones acuosas. Algunos estudios previos han evidenciado que puede promover la saciedad a través de varios mecanismos: aumento del esfuerzo de masticación asociado con el consumo de fibra, inducción de señales cefalicogástricas promotoras de la saciedad, contribución a la distensión gástrica, retraso del vaciado gástrico, ralentización del tiempo de tránsito en el intestino delgado debido a la mayor viscosidad del contenido gastrointestinal, retraso en la absorción de nutrientes y aceleración en la entrega de nutrientes al íleon terminal, donde se transmiten las señales de saciedad.

En el capítulo IV, la **hipótesis de partida** fue que **incorporando glucomanano de konjac** a los pasteles de queso de tal manera que no estuviera totalmente hidratado, se podría observar un aumento en la viscosidad en los productos de su digestión *in vitro* que tendrían los efectos deseados sobre los procesos de distensión y vaciado gástrico y en consecuencia sobre la plenitud y saciedad fisiológicas.

Debido a la alta viscosidad generada durante el batido en presencia de glucomanano fue posible, a la vez que necesario, eliminar totalmente el almidón de maíz y también se pudo utilizar en su elaboración sólo queso fresco desnatado. Esto se tradujo en una reducción considerable del contenido calórico en las muestras reformuladas, lo cual es muy compatible con el objetivo de control de peso buscado con el consumo de esta gama de alimentos.

La muestra de pastel de queso con la menor concentración de glucomanano presentó valores instrumentales de dureza y masticabilidad menores que la muestra control, posiblemente debido a la ausencia de almidón de maíz en su composición, el cual contribuye a la formación de una matriz más compacta, con menor cantidad de agua disponible. El resto de las muestras reformuladas aumentaron significativamente sus valores de dureza, cohesividad y masticabilidad y disminuyeron sus valores de elasticidad con respecto a la muestra control, Se hizo evidente la habilidad de esta fibra soluble para contribuir a formar estructuras más duras, cohesivas y compactas, asociadas con un incremento de la actividad oral para masticar y formar el bolo, lo que contribuye con altas expectativas de capacidad saciante en comparación con texturas más blandas y ligeras.

Con respecto a las propiedades viscoelásticas de los productos de la digestión *in vitro*, las muestras con las dos concentraciones más bajas de glucomanano, presentaron un patrón de comportamiento muy dependiente de la frecuencia (de tipo líquido a bajas frecuencias y de tipo sólido a altas frecuencias), similar al de los productos de la digestión de un complemento dietético comercial y al de una solución acuosa del ingrediente utilizado para elaborar los pasteles en agua. Los valores de los parámetros viscoelásticos fueron mayores para los pasteles digeridos que para las soluciones del ingrediente a la misma concentración, probablemente debido a interacciones con las partículas del pastel digerido, que ayudan a estructurar el sistema. Esto sugiere que el glucomanano como ingrediente podría tener mayor poder saciante que cuando se consume solo (en pastillas o en polvo).

Los productos de la digestión *in vitro* de las muestras con las dos concentraciones de glucomanano mayores, tuvieron un patrón de comportamiento de tipo gel similar al de la muestra control (con poca dependencia de la frecuencia), pero con valores para los módulos viscoelásticos significativamente superiores, lo que indica una contribución del glucomanano a disminuir la fragilidad de la matriz, reforzando su estructura. Esta masa de características sólidas en el estómago podría contribuir con un mayor poder saciante.

Los valores de aceptabilidad de los pasteles de queso disminuyeron con el aumento de la concentración de glucomanano. Esto indicó la importancia de estimar estrategias para reformular también el sabor y para aportar conocimientos acerca del uso beneficioso del ingrediente a los consumidores, orientadas a contrarrestar estos efectos negativos sobre la aceptabilidad en futuros productos a desarrollar.

INTEGRACIÓN DE LAS DIFERENTES ESTRATEGIAS DE REFORMULACIÓN

En el capítulo V, se exploró con mapas proyectivos tanto parciales como global las características sensoriales y no sensoriales de pasteles provenientes de todas las estrategias ya analizadas y su relación con las expectativas de capacidad saciante.

Los resultados indicaron que los ingredientes base de la formulación de pasteles de queso (queso fresco, azúcar, almidón de maíz y huevo) le confieren sus características típicas de sabor y textura. La adición de proteínas de suero lácteo o de soja, salvado de trigo y glucomanano de konjac, así como la eliminación del huevo de la fórmula base, incrementaron la capacidad saciante esperada. Como ya se comentó, estaría relacionado con los cambios en textura (mayor dureza, pasteles más compactos) y, en consecuencia, a una mayor exposición orosensorial. La incorporación de glucomanano provocó los mayores cambios en las características sensoriales de los pasteles de queso; siendo lo más llamativo el descenso en la intensidad del sabor percibido (insípida).

Los mapas proyectivos parciales estuvieron enfocados en las modalidades textura y sabor, y proporcionaron información más específica que no se recoge en un mapa proyectivo global. El mapa proyectivo global mostró el coeficiente RV más alto junto con el mapa proyectivo parcial orientado a sabor, sugiriendo que los atributos de sabor fueron el factor principal que los consumidores tomaron en cuenta para establecer diferencias y similitudes generales entre las muestras, o simplemente les resultó más fácil que usar características de textura. Estos resultados sugirieron que los mapas proyectivos parciales pueden ser una herramienta interesante para explorar la percepción de los consumidores cuando se requiere información sensorial más detallada, particularmente cuando se trabaja con nuevas categorías de alimentos como los productos saciantes.

El estudio de la interrelación entre formulaciones, características sensoriales, aceptabilidad y capacidad saciante esperada podría contribuir grandemente con el desarrollo de nuevos alimentos en la categoría de productos saciantes.

CONCLUSIONES

Las principales conclusiones de la presente tesis doctoral: “Diseño de alimentos saciantes: Estudio de las propiedades físicas, sensoriales y de la capacidad saciante esperada en un postre lácteo sólido tipo tarta de queso” son las siguientes:

- Las texturas más duras y compactas, obtenidas bien sea por la reformulación de los ingredientes minoritarios de los pasteles de queso como por la incorporación de proteínas u otros ingredientes que inmovilizan agua, requirieron un procesamiento oral más prolongado que incrementó las expectativas de su capacidad saciante.

- La incorporación de proteína láctea a los pasteles de queso, generó estructuras más consistentes y laboriosas de masticar, que incrementaron significativamente las expectativas de capacidad saciante en los consumidores manteniendo las características de sabor deseadas en este tipo de productos.

- La adición de proteína de soja a pasteles de queso provocó la aparición de sabores no deseados que afectaron negativamente la aceptabilidad y la intención de consumo y en consecuencia las expectativas sobre su capacidad saciante.

- La aceptabilidad de los pasteles de queso se incrementó con el tiempo de masticación, mientras que su evaluación estática coincidió con los valores del primer impacto en boca. Estos resultados destacaron la importancia de los estudios de aceptabilidad dinámica en el desarrollo de nuevos productos.

- La adición de partículas visibles en pasteles de queso generó percepciones de mayor complejidad. En muestras con valores similares de textura una mayor complejidad influyó positivamente sobre las expectativas de capacidad saciante.

- La adición de concentraciones crecientes de glucomanano de konjac a pasteles de queso incrementó la viscoelasticidad de los productos de la digestión gástrica *in vitro*, lo cual podría favorecer potencialmente los mecanismos postingestivos de saciedad fisiológica.

- El glucomanano de konjac disminuyó la intensidad del sabor en pasteles de queso, por lo que debe mejorarse su aceptabilidad mediante reformulación del sabor y aumentando la información a los consumidores sobre las propiedades beneficiosas de esta fibra soluble.

- Los mapas proyectivos parciales de textura y sabor permitieron explorar la percepción de los consumidores aportando información sensorial específica. Este resultado es particularmente interesante para trabajar con nuevas categorías de productos como los alimentos saciantes.

- Los métodos de evaluación sensorial con consumidores resultaron rápidos y eficaces como herramientas para explorar las expectativas de capacidad saciante y su relación con las características de alimentos reformulados. Su combinación con técnicas instrumentales proporcionó consistencia a los resultados y favoreció su análisis e interpretación.

- El modelo pastel de queso y los ingredientes incorporados, representa un producto final real y tecnológicamente viable que podría ampliar la gama de alimentos funcionales disponibles en el mercado, orientados al control de peso y al tratamiento de la obesidad.