UNIVERSIDAD POLITECNICA DE VALENCIA

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

INSTITUTO DE AGROQUÍMICA Y TECNOLOGÍA DE ALIMENTOS

Efecto de la adición de inulina en las características físicas y sensoriales de batidos lácteos

Tesis Doctoral

Presentada por:

Beatriz Villegas Pascual

Dirigida por:

Dra. Elvira Costell Ibáñez

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Dª Elvira Costell Ibáñez, Profesora de Investigación del Instituto de Agroquímica y Tecnología de Alimentos del Consejo Superior de Investigaciones Científicas,

HACE CONSTAR:

que la memoria titulada **"Efecto de la adición de inulina en las características físicas y sensoriales de batidos lácteos"** que presenta Dª Beatriz Villegas Pascual para optar al grado de Doctor por la Universidad Politécnica de Valencia, ha sido realizada en el Instituto de Agroquímica y Tecnología de alimentos (IATA-CSIC) bajo su dirección y que reúne las condiciones para ser defendida por su autora.

Valencia, 28 abril de 2008

Fdo: Dra. Elvira Costell Ibáñez

Me parece mentira estar frente a esta página en blanco sin saber qué escribir... ¡a ver si me va a costar más ésta sola que toda la tesis! Bueno, en primer lugar y para que no se me olvide nadie, porque como dice el refrán, "es de bien nacidos el ser agradecidos", quiero expresar mi agradecimiento a todos aquellos que consideren que se lo debo de alguna manera, porque nos hayamos reído un poco (o un mucho), porque me hayan ayudado en algo (¡o en muchos "algo"!), porque me hayan enseñado, sufrido,... y no sigo porque si no, no acabo ni esto es el anuncio de la Coca-cola. Después de las gracias generalizadas, la primera persona a la que quiero expresar mi agradecimiento es a Elvira. Menos mal que quería porque me quedo sin palabras para escribir lo que quisiera, pero al menos, gracias por hacerme crecer profesional y personalmente. A Inma, creo que lo que más te agradezco es aguantar el tirón, tienes más paciencia que el santo Job... a mis compañeros del laboratorio durante estos años Amparo, Luis, Pepe y Sara, por las risas, las sonrisas, la ayuda incondicional y las palmaditas de ánimo. ¡Ah! y a Amparo doble agradecimiento por abrirme los ojos (que no la mente...) a esa linda ciencia que es la estadística... a Luis Durán, por su apoyo lingüístico y contarme el chiste del jaguar y a Luis Izquierdo, por su apoyo estadístico y recordarme que antes del WINDOWS existía el MS DOS... a mis traductores valencians; a "las chicas del 208", por darme los "Buenos días", invitarme a comer tartas de cumpleaños, a ir a la mascletà y demás eventos festivos. A ver, a ver... ¡claro! a todos aquellos que sin rechistar (que no son tantos) o rechistando (algunos más) participaron en la cata de los maravillosos batidos que con tanto esmero preparaba, a los catadores fieles, muchas gracias, porque en una tesis de temática sensorial habría sido harto difícil prescindir de vosotros. Y a esos amigos incondicionales (y también a los de condición) porque me han llenado de experiencias (todo muy en la línea) durante estos cuatro años.

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Y eso era casi todo...

RESUMEN

Efecto de la adición de inulina en las características físicas y sensoriales de batidos lácteos

La investigación realizada en esta tesis se ha centrado en dos temas: poner a punto la metodología para investigar la influencia de las opiniones, actitudes y expectativas de los consumidores en la aceptación de productos con características nutricionales especiales y en desarrollar y optimizar la aceptabilidad de nuevas formulaciones de batidos lácteos, con bajo contenido en grasa y con características prebióticas.

Para analizar la posible influencia de las características, actitudes y opiniones de los consumidores y de las expectativas generadas por la información nutricional en la aceptabilidad, se seleccionaron dos tipos de batidos comerciales con sabor a vainilla y con características sensoriales y nutricionales diferentes (lácteos y de soja). Se investigó la influencia de las características demográficas, de los hábitos de consumo y de las preferencias individuales de los consumidores en la aceptación de ambos productos y se analizó la relación entre las diferencias sensoriales percibidas y la aceptabilidad de los mismos. Los resultados revelaron que las diferencias en aceptabilidad entre ambos tipos de bebidas estaban más relacionadas con los atributos sensoriales de las mismas que con las otras características estudiadas (criterios demográficos, hábitos de consumo y preferencias individuales). En una segunda experiencia, se investigó cómo influían las expectativas generadas en los consumidores por el tipo de producto y por la información nutricional suministrada en el envase sobre el mismo y ciertas opiniones y actitudes de los consumidores en la aceptación y en la intención de compra de ambos tipos de bebidas. Los resultados obtenidos indicaron que la información nutricional más que afectar a la aceptabilidad del producto, influía en la intención de compra del mismo y

que algunas actitudes de los consumidores, como las relacionadas con el mayor o menor interés en alimentarse de forma saludable, modificaban la respuesta de los consumidores ante la confirmación o la no confirmación de las expectativas generadas por la información nutricional.

Para diseñar y optimizar la formulación de nuevas bebidas lácteas de carácter prebiótico, se seleccionó un ingrediente de efectos saludables contrastados, la inulina. Se estudió la influencia de la adición de inulina de distinto grado de polimerización en el comportamiento de flujo y en la viscosidad y cremosidad percibidas sensorialmente en sistemas modelo de bebidas lácteas elaboradas con leche entera y con leche desnatada. Los resultados indicaron que el efecto de la concentración de inulina en el comportamiento de flujo y en la viscosidad y cremosidad de las bebidas fue diferente en función del grado de polimerización y del tipo de leche utilizado. La inulina de longitud de cadena larga fue la que proporcionó los mayores incrementos de viscosidad instrumental y sensorial y de cremosidad, seguida de la inulina de cadena corta y de la inulina nativa. Paralelamente se puso de manifiesto que la capacidad de la inulina como sustituto de grasa dependía, no sólo de la longitud media de las cadenas, sino también de la concentración de inulina añadida. En función de estos resultados se planificó la optimización de nuevas formulaciones de bebidas lácteas elaboradas con leche desnatada y con inulina añadida utilizando el método de la superficie de respuesta con un diseño rotacional centrado de segundo orden variando las concentraciones de inulina y de azúcar. El diseño se aplicó a dos series de muestras, una con inulina de cadena corta y otra, con inulina de cadena larga. Se modelizó la variación de la aceptabilidad en función de las variaciones en las concentraciones de los ingredientes y se seleccionaron las formulaciones de aceptabilidad óptima para cada tipo de inulina. Finalmente se comparó la aceptabilidad de las bebidas elaboradas con las formulaciones óptimas seleccionadas y entre cada una de ellas y una muestra control elaborada con leche entera y sin inulina añadida. No se detectaron diferencias significativas en la aceptabilidad de las nuevas formulaciones bajas en grasa, ni entre la de cada una de ellas y la muestra control.

RESUM

Efecte de l'addició de inulina en les característiques físiques i sensorials de batuts lactis

La investigació realitzada en aquesta tesi s'ha centrat en dos temes: posar a punt la metodologia per a investigar la influència de les opinions, actituds i expectatives dels consumidors en l'acceptació de productes amb característiques nutricionals especials i a desenvolupar i optimitzar l'acceptabilitat de noves formulacions de batuts lactis, amb baix contingut en greix i amb característiques prebiòtiques.

Per a analitzar la possible influència de les característiques, actituds i opinions dels consumidors i de les expectatives generades per la informació nutricional en l'acceptabilitat, es van seleccionar dos tipus de batuts comercials amb sabor a vainilla i amb característiques sensorials i nutricionals diferents (lactis i de soia). Es va investigar la influència de les característiques demogràfiques, dels hàbits de consum i de les preferències individuals dels consumidors en l'acceptació d'ambdós productes i es va analitzar la relació entre les diferències sensorials percebudes i l'acceptabilitat de les mostres. Els resultats van revelar que les diferències en acceptabilitat entre ambdós tipus de begudes estaven més relacionades amb els atributs sensorials de les mateixes que amb les altres característiques estudiades (criteris demogràfics, hàbits de consum i preferències individuals). En una segona experiència, es va investigar com influïen les expectatives generades en els consumidors pel tipus de producte i per la informació nutricional subministrada en l'envàs i certes opinions i actituds dels consumidors en l'acceptació i en la intenció de compra d'ambdós tipus de begudes. Els resultats obtinguts van indicar que la informació nutricional més que afectar a l'acceptabilitat del producte, influïa en la intenció de compra del mateix i que algunes

actituds dels consumidors, com les relacionades amb el major o menor interés en alimentar-se de forma saludable, modificaven la resposta dels consumidors davant la confirmació o la no confirmació de les expectatives generades per la informació nutricional.

Per a dissenyar i optimitzar la formulació de noves begudes làcties de caràcter prebiòtic, es va seleccionar un ingredient d'efectes saludables comprovats, la inulina. Es va estudiar la influència de l'addició de inulina de diferent grau de polimerització en el comportament de flux i en la viscositat i cremositat percebudes sensorialment en sistemes model de begudes làcties elaborades amb llet sencera i amb llet desnatada. Els resultats van indicar que l'efecte de la concentració de inulina en el comportament de flux i en la viscositat i cremositat de les begudes va ser diferent en funció del grau de polimerització i del tipus de llet utilitzat. La inulina de longitud de cadena llarga va ser la qual va proporcionar els majors increments de viscositat instrumental i sensorial i de cremositat, tot seguit de la inulina de cadena curta i de la inulina natural. Paral·lelament es va posar de manifest que la capacitat de la inulina com substitut de greix depenia, no només de la longitud mitja de les cadenes, sinó també de la concentració de inulina afegida. En funció d'aquests resultats es va planificar l'optimització de noves formulacions de begudes làcties elaborades amb llet desnatada i amb inulina afegida utilitzant el mètode de la superfície de resposta amb un disseny rotacional centrat de segon ordre variant les concentracions de inulina i de sucre. El disseny es va aplicar a dues sèries de mostres, una amb inulina de cadena curta i altra, amb inulina de cadena llarga. Es va modelitzar la variació de l'acceptabilitat en funció de les variacions en les concentracions dels ingredients i es van seleccionar les formulacions d'acceptabilitat òptima per a cada tipus de inulina. Finalment es va comparar l'acceptabilitat de les begudes elaborades amb les formulacions òptimes seleccionades i entre cadascuna d'elles i una mostra control elaborada amb llet sencera i sense inulina afegida. No es van detectar diferències significatives en l'acceptabilitat de les noves formulacions baixes en greix, ni entre la de cadascuna d'elles i la mostra control.

SUMMARY

Effect of inulin addition on physical and sensory properties of milk beverages

The research developed in this thesis was focused on two topics: to develop the methodology to study the influence of consumer beliefs, attitudes and expectations on the acceptability of products with special nutritional characteristics and to develop and optimise the acceptability of new milk beverages formulations with low fat content and prebiotic characteristics.

To analyse the influence of consumer characteristics, beliefs and attitudes and of the expectations created by nutritional information on the acceptability, two types of commercial vanilla beverages (milk and soymilk) with different nutritional and sensory characteristics were selected. The influence of consumer demographic characteristics, consumption habits and individual preferences on acceptability of both types of products was studied and the relationship between sensorially perceived differences and acceptability of products was analysed. Results showed that differences in acceptability between both types of beverages were more related with sensory attributes than with the other studied characteristics (demographics, consumption habits and individual preferences). In a second study, the influence of expectations created by the type of product and the nutritional information indicated on the packages and consumer beliefs and attitudes on acceptability and purchase intention was studied. Results indicated that the nutritional information influenced purchase intention more than product acceptability, and that some consumer attitudes, as that related with the interest in healthy eating, changed their responses before confirmation or not of expectations created by the nutritional information.

For designing and optimising the formulation of new prebiotic milk beverages, an ingredient with proved healthy effects, inulin, was selected. The influence of the addition of inulin with different chain lengths on flow behaviour and on perceived thickness and creaminess in low-fat and full-fat milk beverage model systems was studied. Results showed that inulin concentration effect on flow behaviour and on thickness and creaminess of beverages was different depending on the chain length of inulin and on the type of milk used. The higher increases on instrumental viscosity, and sensory thickness and creaminess were obtained with long chain length inulin, followed by short chain length and native inulins. Parallelly, it was stated that the potential of the different types of inulin to act as fat substitutes depended on their chain length as well as on the concentration of added inulin. Depending on these results, the optimisation of new milk beverage formulations elaborated with skimmed milk and added inulin was planned using response surface methodology, according to a two-factor central composite rotatable design, varying inulin and sucrose concentration. The design was applied to two lots of samples, one with short chain length inulin and another one with long chain length inulin. The relationship between acceptability variation and the variations in ingredient concentrations was obtained, and formulations corresponding to the optimum acceptability for each inulin type were selected. Finally, acceptability of beverages elaborated according to the two optimum formulations were compared between them and then each one of the optimum formulations with a control sample prepared with whole milk and without inulin added. No significant differences in acceptability between the two new low-fat beverages were found and they showed no differences in acceptability when compared with the full fat control sample.

ÍNDICE GENERAL

INTRODUCCIÓN GENERAL

Los alimentos funcionales

El creciente interés por una alimentación saludable ha dado lugar a la aparición en el mercado de una nueva gama de alimentos y productos que, además de nutrir, mejoran la salud incrementando el bienestar y reduciendo el riesgo de contraer determinadas enfermedades. Estos alimentos se denominan genéricamente funcionales y, de acuerdo con los resultados de la acción concertada europea "Functional Food Science in Europe", se definen como *"un alimento natural o uno al que se le ha añadido o eliminado componentes, por vía tecnológica o biotecnológica, de forma que se ha demostrado satisfactoriamente que tiene un efecto beneficioso para la salud además de los efectos nutricionales habituales"* (EUR 18591, 2000). La importancia actual de los alimentos funcionales en el mercado es variable y difícil de determinar, pero está claro que tienen un elevado potencial de crecimiento (Sloan, 2006). Las estimaciones indican que el consumo de estos alimentos en Europa tiende a incrementarse considerablemente y que puede llegar a alcanzar una cuota cercana al 5% del mercado de alimentos y bebidas en la segunda década de este siglo (Menrad, 2003). Las mejores expectativas de crecimiento en el sector de los alimentos funcionales están en el mercado de las bebidas y de los productos semisólidos, más fáciles y cómodos de consumir que los alimentos sólidos. Entre los distintos sectores, el de los productos lácteos es uno de los que más ha cambiado por la introducción de nuevos productos con características saludables. A los productos ya tradicionales, como los desnatados o con características probióticas, se ha añadido, en los últimos años, una amplia gama de leches fermentadas de carácter pre- o probiótico, de yogures y de leche con distintos principios activos adicionados. En España, no se ha encontrado información sobre el consumo actual de alimentos funcionales lácteos pero según el MAPA (2007), de 2005 a 2006 el consumo de leche disminuyó en un 3.7%, mientras que el de los derivados lácteos, se incrementó en un 3.0%. Es lógico deducir que esta variación en el consumo está relacionada con el incremento en el mercado de productos lácteos funcionales.

Partiendo de la base de que los alimentos funcionales deben ser capaces de modular algún parámetro fisiológico relacionado con el estado de salud o con la prevención de determinadas enfermedades, su diseño y desarrollo se suele iniciar por una de las siguientes vías: 1) Modificación de la composición de las materias primas. Por ejemplo, variando la dieta de determinados animales para conseguir productos de características nutricionales distintas a las habituales (huevos enriquecidos con Omega-3, o leche enriquecida en ácido linoleico conjugado) o aplicando técnicas de biología molecular que permitan obtener nuevos alimentos mediante su modificación genética; 2) Modificación de los procesos de transformación (fermentación, extrusión, tratamiento térmico, etc.) de forma que durante el mismo, se favorezca o se incremente la formación de compuestos con una actividad biológica específica; y 3) Modificación de la formulación de un alimento tradicional eliminando o sustituyendo determinados ingredientes (grasa, azúcar, etc.) o adicionando compuestos de características saludables contrastadas (fibra soluble, omega-3, vitaminas, fitoesteroles, etc.) (Fogliano y Vitaglione, 2005). De estas tres opciones, la última es, al menos teóricamente, la más simple y la más utilizada en el desarrollo de nuevos productos funcionales. Sin embargo, puede presentar problemas derivados de las posibles interacciones entre los ingredientes funcionales y los componentes de la matriz alimentaria. El efecto de estas interacciones se puede traducir, en el aspecto nutricional, en una disminución de la biodisponibilidad del principio activo adicionado o en la variación de las condiciones óptimas para su absorción y respecto a su calidad, en una alteración de las características sensoriales del producto final que provoque el rechazo del mismo por el consumidor.

De hecho, el mercado de los alimentos funcionales se caracteriza por una alta proporción de productos que fracasan comercialmente. En algunos casos, es fácil detectar importantes errores en el diseño y desarrollo de alimentos funcionales que podría haberse evitado utilizando mejores estrategias y controlando los puntos clave de las mismas. Es evidente que la identificación de nuevos compuestos bioactivos (Dillard y German, 2000; Madley, 2001; Lindenmeier et al., 2002; Silva y Malcata, 2005) es un punto importante y necesario en el diseño de alimentos funcionales pero el valor real de cada uno de ellos dependerá, en primer lugar, de la cantidad del mismo que el consumidor necesite incluir en su dieta para que resulte beneficioso para su salud y también, de que las características de la matriz alimentaria a la que se va a incorporar, no alteren la estabilidad y biodisponibilidad del principio activo en el producto final (Clydesdale, 2004). Aún teniendo en cuenta y controlando estos aspectos, el éxito de un alimento funcional en el mercado va a depender de que responda a las necesidades del consumidor (Urala y Lähtennmäki, 2004) y del grado de satisfacción que sea capaz de proporcionarle (Heldman, 2004). Por ello, la opinión del consumidor debe ser tenida en cuenta no sólo para evaluar la aceptabilidad del producto final sino desde el inicio del proceso de su desarrollo (van Kleef et al., 2002; Sijtsema et al., 2002). Otra cuestión a tener en cuenta es que la respuesta final del consumidor frente a este tipo de alimentos, como ocurre también con otras clases de alimentos “especiales” como los orgánicos o los modificados genéticamente, estará matizada por la opinión o conocimiento que el consumidor tenga sobre ellos (Newsholme, 2001; Magnusson y Koivisto, 2002; Saba y Vasallo, 2002). En principio, para entender y poder predecir la respuesta del mercado frente a un alimento funcional, es necesario analizar conjuntamente la incidencia en la misma, tanto de su calidad sensorial, como de las actitudes, opiniones y expectativas que el consumidor tenga sobre dicho producto.

En este contexto, para diseñar y desarrollar nuevos alimentos funcionales que, además de aportar beneficios específicos para la salud, sean aceptables para el consumidor es necesario: 1) Seleccionar el compuesto bioactivo y la matriz alimentaria a la que se va a adicionar; 2) Investigar la influencia de la composición y de la interacción entre los distintos ingredientes en las propiedades físicas y sensoriales del producto; 3) Optimizar la aceptabilidad del producto; y 4) Estudiar la influencia de las opiniones, actitudes y expectativas del consumidor en la aceptación.

La inulina. Características funcionales y tecnológicas

En la mayoría de los países europeos, la inulina está considerada como un ingrediente alimentario natural y seguro. En Estados Unidos, goza de estatus GRAS (Coussement, 1999; Kaur y Gupta, 2002; Milo, 2004). La inulina es un componente natural de varias frutas y hortalizas aunque su obtención industrial se realiza mayoritariamente a partir de las raíces de la achicoria mediante un proceso de extracción con agua caliente seguido de una etapa de purificación y de otra de cristalización. La inulina nativa es una mezcla de cadenas de oligómeros y polímeros con un número variable de moléculas de fructosa, unidas por enlaces β $(2\rightarrow1)$ que suele incluir en su extremo, una molécula de glucosa. Precisamente, la configuración β de este enlace es la que le confiere su carácter de fibra dietética (Flamm et al., 2001) ya que es la responsable de que la inulina sea resistente a la hidrólisis en el intestino delgado porque los enzimas digestivos que actúan en el mismo son específicos para los enlaces alfa-glicosídicos. El grado de polimerización de las cadenas que la integran oscila entre 2 y 60 unidades, y suele caracterizarse por el grado de polimerización medio que en la inulina nativa es, aproximadamente, de 12. Mediante la hidrólisis enzimática parcial de la inulina nativa con una endo-inulinasa, se obtiene la oligofructosa, con un grado de polimerización que oscila entre 2 y 7 y cuyo valor medio es de 4. Aplicando métodos físicos (ultrafiltración, cristalización, etc.), para eliminar los oligómeros de grado de polimerización inferior a 10, se obtiene una inulina de cadena larga con un grado de polimerización medio que oscila entre 22 y 25 (Franck, 2002; Moerman et al., 2004).

La ingestión de inulina puede aportar, no solo los beneficios inherentes a su condición de fibra dietética (reducción de los niveles de lípidos y de colesterol en la sangre, regulación del tránsito intestinal, incremento de la adsorción de calcio, etc.) (Flamm et al., 2001) sino también, los derivados de su carácter prebiótico, relacionados sobre todo con la estimulación del crecimiento de las bifidobacterias (Roberfroid et al.,1998; Roberfroid y Slavin, 2000) y con la regulación de la flora intestinal del colon disminuyendo el crecimiento de las bacterias de las clases fusobacteria y clostridia (Kaur y Gupta, 2002). Recientemente, Roberfroid (2005) ha resumido las posibles funciones fisiológicas que pueden tener los fructanos de tipo inulina, clasificándolas en tres grupos: a) Funciones suficientemente contrastadas científicamente, en las que se incluyen, además de las citadas anteriormente, la mejora en la absorción de determinados minerales (Ca y Mg) y la reducción de la lipogénesis hepática; b) Funciones sobre las que hay estudios convincentes pero que necesitan todavía una confirmación, como las relacionadas con el metabolismo del colesterol, con la función inmune, con la atenuación de los procesos inflamatorios o con la reducción del riesgo de padecer cáncer de colon y finalmente; y c) Funciones relacionadas con los resultados prometedores de algunas investigaciones recientes (absorción gastrointestinal de otros minerales: Fe, Cu, Zn), incremento de la resistencia a las infecciones intestinales, reducción del riesgo de metástasis en los procesos cancerosos, etc.).

El efecto prebiótico de la inulina depende de varios factores, especialmente de la composición de la flora intestinal de cada individuo. Cuanto menor es la cantidad de bífidus en dicha flora, mayor es el efecto. Debido a esta variabilidad individual, no se puede establecer una relación directa entre la ingesta de inulina y el incremento de bífidus, ni definir una dosis de validez general (Roberfroid, 2005). No obstante, un consumo mínimo de 5g/día se considera que puede ser suficiente para incrementar la proporción de bífidus en la microflora intestinal aunque también es cierto que la mayoría de los estudios realizados *in vivo,* tanto con animales como en seres humanos se han realizado suplementando la dieta con cantidades mayores (Roberfroid et al., 1998; Roberfroid y Slavin, 2000). Aunque hay pocos trabajos en los que se comparen los efectos fisiológicos de las inulinas de distinto grado de polimerización, lo que sí es evidente es que aunque todos estos macronutrientes son fermentados por las bifidobacterias en el colon, la velocidad de fermentación depende de su grado de polimerización. La de los oligómeros con grado de polimerización inferior a 10 es, aproximadamente, el doble que la de las moléculas más largas (Roberfroid et al., 1998) por lo que, en función de la longitud de las cadenas, la fermentación se produce en zonas distintas del colon, la actividad metabólica tiene distinta duración y se pueden producir variaciones en su efecto fisiológico (Coudray et al., 2003; Biedrzycka y Bielecka, 2004; Roberfroid, 2005; Van Loo et al., 2005). Ello parece indicar que la utilización de inulinas de distinto grado de polimerización podría dar lugar a alimentos con diferentes efectos fisiológicos.

Además de sus efectos beneficiosos para la salud, la inulina tiene unas propiedades tecnológicas interesantes, como edulcorante de contenido calórico reducido, como sustituto de grasa, o por su capacidad para modificar la textura (Tungland y Meyer, 2002). Estas propiedades están ligadas al grado de polimerización de sus cadenas. La de cadena corta u oligofructosa es mucho más soluble y más dulce que la inulina nativa, con un perfil de dulzor similar al de la sacarosa y menor contenido calórico (1-2 Kcal/g) aunque con un poder edulcorante inferior (30-35%). Puede ser útil para reemplazar parcialmente la sacarosa de una formulación o sustituirla totalmente cuando se combina con otros edulcorantes acalóricos. La inulina de cadena larga, con grado de polimerización alto (22-25), es más estable térmicamente, menos soluble y más viscosa que la nativa (Wada et al., 2005), y tiene una capacidad como sustituto de grasa, que es prácticamente el doble que la de la inulina nativa (Voragen, 1998; Coussement, 1999). Sus propiedades como sustituto de grasa se atribuyen a su capacidad para formar microcristales que interaccionan entre sí formando pequeños agregados que ocluyen gran cantidad de agua, originando una textura cremosa y fina que proporciona una sensación bucal similar a la de la grasa (Frank, 2002; Kaur y Gupta, 2002; Bot et al., 2004).

Optimización de la aceptabilidad

El proceso de optimización de una formulación consiste en una serie de acciones sistematizadas que se ejecutan cuando se desarrolla un producto. Cuando se pretende optimizar la calidad sensorial de un producto formulado, el objetivo es obtener el mejor entre los de una clase determinada, a partir de unos ingredientes concretos (Fishken, 1983; Pastor et al., 1996; Damasio et al., 1999; Gan et al., 2006; Acosta et al., 2008). Uno de los métodos más utilizados para optimizar productos formulados es el de la superficie de respuesta, que permite relacionar las variaciones en la respuesta con las variaciones de los factores previamente seleccionados, aplicando un diseño estadístico apropiado (Gacula, 1993; Khuri y Cornell, 1987). La metodología de la superficie de respuesta consta de cuatro etapas fundamentales (Gacula, 1993): 1) Identificación y selección de los factores y sus niveles, mediante estudios previos que permitan determinar los factores más relevantes en la aceptación del producto y los intervalos de variación de dichos factores que permitan detectar los posibles cambios en la dirección de las respuestas; 2) Diseño experimental. Los más utilizados son los llamados rotacionales compuestos centrados de segundo orden. La estructura del diseño parte inicialmente del establecimiento de los límites de los factores variables. El número y composición de las muestras se determina en función de los requerimientos del diseño y de acuerdo con la experiencia (Sidel et al., 1994); 3) Medida de la variable respuesta. En estudios de optimización de la aceptabilidad las medidas de aceptación o preferencia constituyen la variable dependiente, mientras que las variables independientes suelen ser los ingredientes o las condiciones del proceso; y 4) Análisis e interpretación de los resultados. Una vez obtenidos los datos experimentales, se procede a analizar la relación entre la variable dependiente y las independientes, ajustándola a una ecuación de segundo orden que incluye los efectos lineales, cuadráticos y de la interacción entre los factores considerados. Las ecuaciones obtenidas pueden representarse gráficamente como una superficie en tres dimensiones o con un gráfico bidimensional del contorno asociado.

Influencia de las opiniones, actitudes y expectativas del consumidor en la aceptación

La investigación sobre la aceptabilidad de los alimentos se ha basado tradicionalmente en el análisis de la relación entre la composición, estructura y propiedades físicas del alimento y su aceptabilidad. Actualmente, el planteamiento es distinto: no todas las diferencias en composición, estructura o propiedades físicas del alimento dan lugar a diferencias perceptibles sensorialmente, ni todas las diferencias sensoriales percibidas provocan cambios en la aceptación del alimento. Además, los criterios que aplica el consumidor para elegir y consumir un alimento no siempre se explican por las diferencias percibidas en su calidad sensorial (Mela, 2001). Además de las características propias del alimento y de las sensaciones que el consumidor experimente al ingerirlo, la opinión que cada consumidor tenga sobre las características nutritivas o la composición del producto (Bruhn et al., 1992), sobre la seguridad del mismo (Wilcock et al., 2004) e, incluso, sobre su marca comercial (Guerrero et al., 2000) o sobre su precio (Caporale y Monteleone, 2001; di Monaco et al., 2005), condicionan su elección en el momento de la compra y pueden modificar el grado de placer al consumirlo. Este hecho es especialmente importante en la aceptación o rechazo de algunos tipos de alimentos como los funcionales, que se presentan ante el consumidor como una posible alternativa a los alimentos convencionales (Urala y Lähtennmäki, 2004; Verbeke et al.; 2005, Verbeke, 2006).

Por ello, durante los últimos años, se está ampliando y modificando la metodología aplicable al estudio de los factores que influyen en la aceptabilidad de los alimentos incorporando técnicas cualitativas y cuantitativas, como los cuestionarios con escalas de Likert, para obtener información sobre las opiniones y actitudes de los consumidores frente a determinados tipos de alimentos (Chambers y Smith, 1991; Roininen et al., 1999; Barrios y Costell, 2004) y analizando la influencia de las expectativas del consumidor en la aceptabilidad (Newsholme y Wong, 2001).

El concepto de expectativa ha sido utilizado durante muchos años por los psicólogos para explicar determinados comportamientos humanos. En el campo de los alimentos, las expectativas del consumidor juegan un doble papel: influyen en la elección del alimento antes de consumirlo y en su posterior aceptación o rechazo después de su consumo. La respuesta del consumidor dependerá de que el producto satisfaga o no sus expectativas (Cardello, 1994). Desde el punto de vista práctico, la cuestión que se plantea es determinar cómo la confirmación o no confirmación de las expectativas afectan a la percepción y aceptación del alimento. Para explicar los diferentes comportamientos observados, se han propuesto cuatro modelos: 1) Asimilación, cuando la evaluación de la aceptabilidad de un producto se modifica en función de la dirección de la expectación; 2) Contraste, cuando la evaluación del producto cambia en dirección opuesta a la expectación; 3) Asimilación-contraste, que explica el efecto de las expectativas en función de la magnitud de la no confirmación; y 4) Negatividad generalizada, que explica los comportamientos que se producen cuando la no confirmación da lugar a una disminución en la aceptabilidad el producto (Tuorila et al., 1994a; Lange et al., 1999; Caporale y Monteleone, 2001, Newsholme y Wong, 2001). El estudio de la influencia de las expectativas en la aceptación de diferentes tipos de alimentos se ha incrementado notablemente en los últimos años y está consolidándose como una técnica interesante. Por ejemplo, Siret e Issanchou (2000) analizaron la influencia de la información sobre el método de elaboración (tradicional y no tradicional) en la aceptabilidad del paté y Jaeger y MacFie (2001), el efecto de la imagen y de la información previa sobre la aceptación de distintas variedades de manzana. En el caso de los alimentos funcionales, es lógico pensar que la información sobre su posible influencia en la salud pueda afectar a su aceptación. Aunque, hasta hoy, no son muy abundantes los estudios sobre este tema, sí existe alguno sobre el efecto de la información previa en la aceptabilidad de los alimentos bajos en grasa (Tuorila et al., 1994b), del yogur desnatado (Kähkönen et al., 1997), de productos de bollería con fibra añadida (Mialon et al., 2002), de diferentes tipos de bebidas de soja (Behrens et al., 2007) o de sopas vegetales (Di Monaco et al., 2007). Resulta interesante considerar el efecto que la información sobre las características saludables de los alimentos funcionales tiene en su aceptación por la incidencia que podría tener en el diseño de nuevos productos.

El análisis de los conocimientos de que se dispone actualmente, tanto en lo relativo a la metodología aplicable para analizar la influencia de la composición y de la interacción entre los distintos ingredientes en las propiedades físicas y sensoriales de los alimentos, como en lo referente a los factores que influyen en su aceptabilidad por el consumidor, permiten abordar con mas garantías el desarrollo de alimentos funcionales de buena calidad sensorial.

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OBJETIVOS

Este trabajo tenía dos objetivos generales:

1. Desarrollar y poner a punto una metodología para investigar la influencia de las opiniones, actitudes y expectativas de los consumidores en la aceptación de productos con características nutricionales especiales.

2. Desarrollar y optimizar la aceptabilidad de nuevas bebidas lácteas, bajas en grasa y con características prebióticas.

Para conseguirlos, se establecieron los siguientes objetivos concretos:

1.1. Determinar la influencia de las características demográficas, hábitos de consumo y preferencias individuales de los consumidores en la aceptación de dos tipos de bebidas comerciales de vainilla (lácteas y de soja) y analizar la relación entre las diferencias sensoriales percibidas y la aceptabilidad de las mismas.

1.2. Estudiar cómo influyen las expectativas generadas por la información nutricional y las opiniones y actitudes de los consumidores en la aceptación y en la intención de compra de ambos tipos de bebida.

1.3. Analizar la influencia de la adición de inulinas de distinto grado de polimerización en el comportamiento de flujo y en la viscosidad y cremosidad percibidas sensorialmente en sistemas modelo de bebidas lácteas.

1.4. Optimizar la aceptabilidad de formulaciones de batidos lácteos, bajos en grasa y de características prebióticas con inulinas de distinto grado de polimerización adicionadas.

CAPÍTULO 1

COLOUR AND VISCOSITY OF MILK AND SOYBEAN VANILLA BEVERAGES. INSTRUMENTAL AND SENSORY MEASUREMENTS

Beatriz Villegas, Inmaculada Carbonell and Elvira Costell

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ABSTRACT

BACKGROUND: Differences in instrumental measurements of colour and viscosity were analysed in six commercial samples of vanilla beverages, three of milk and three of soybean. Sensory differences between them were assessed and an analysis was made of whether the perceived differences had any influence on consumer preferences with respect to these attributes.

RESULTS: The milk beverages were a stronger yellow in colour ($45.05 \leq b^* \leq 60.02$) than the soybean beverages ($18.46 \leq b^* \leq 21.96$). The flow of all samples was Newtonian, showing viscosity values in the range 4.34 - 7.92 mPa s. Significant differences in viscosity were detected between samples. Sensory results revealed that the vanilla milk samples were perceived as having a stronger yellow colour and being thicker than the vanilla soymilk samples. The majority of people surveyed (n = 142) preferred the samples that were deeper yellow in colour; moreover the thickness of milk samples was significantly more acceptable than that of soymilk samples.

CONCLUSION: The instrumental measurement of colour relates well to the perceived differences in the colour of these products and explains the differences in consumer preferences. However, the instrumental viscosity values do not relate well to the thickness perceived or to the differences in acceptability of the beverages.

Keywords: vanilla beverages, soybean, milk, colour, viscosity, acceptability

1. INTRODUCTION

There is growing interest in soybean products in the Western world, mainly owing to the health benefits that soybean consumption affords. Soybean is an important protein source, a potential source of bioactive peptides and contains high levels of minerals and amino acids.[1,2] The consumption of soy products has been associated with cardiovascular benefits, with reducing the risk of osteoporosis and breast cancer and with alleviating symptoms associated with menopause.[3] Soymilk is one of the more popular soybean products, with plain and vanilla being the most common flavours, although the beverage is being developed in a wide variety of other flavours.[4] As well as the health benefits they provide, soymilk beverages can be an interesting alternative for consumers who are lactose-intolerant, allergic to milk or who avoid milk for any other reason.[5] The main problem in the acceptance of soymilk and soymilk beverages is that their sensory characteristics do no match those of milk and milk beverages and that, from the consumer's viewpoint, health is important but not at the expense of sensory quality.[6,7] To increase the acceptability of soymilk beverages, one must gain a better understanding of its chemical, physical and sensory characteristics and how each of these influences the final response of the consumer.

The main factor limiting the consumption of soymilk products is related to their flavour, which is commonly referred to as "beany", although more specific descriptions, including terms such as grassy, painty, astringent, bitter, rancid, etc., have been developed by sensory descriptive analyses of these products.[4,6,8]

Various authors have tried to solve the problem of undesirable flavour in soymilk beverages using different approaches. Undesirable odours and tastes of soymilk are considered to come mainly from the products of the oxidation of unsaturated lipids, a reaction catalysed by the presence of lipoxygenases and hydroperoxide lyase. Therefore, in an attempt to modify this odour profile, soy varieties with a lower lipoxygenase content have been developed in order to diminish the degree of fatty acid oxidation during the soymilk manufacturing process; however, results so far are not completely satisfactory.[9] Another possible solution has been based on masking the soy flavour by designing beverages with other ingredients, e.g. chocolate-flavoured peanut-soy beverage,[7] coco-soy beverage[10] or wild blueberry-soy beverage,[11] but in most cases the flavour of the beverage obtained was significantly less acceptable than that of the control sample.

Because of the importance of reducing undesirable flavours and odours in order to make soymilk beverages more widely acceptable, little attention has been paid to other sensory attributes such as colour and viscosity, which can undoubtedly also have an influence on the final acceptability of a product. Some authors have described the presence of undesirable characteristics such as chalky, dry, oily, etc. in the texture of these beverages,[6,7] while others have observed up to what point the addition of stabilisers such as gelatine, pectin or gum acacia to soybean products improved the acceptability not only of their texture but also of their flavour.[10,12]

It is clear that a consumer's final response is based on his/her perception of the different attributes that make up the sensory quality of a product as a whole and that the sensation depends not only on the strength of these traits but also on the effect of interactions, both physiological and cognitive, between them. There is little information available on the differences in colour and viscosity between milk beverages and soymilk beverages, and frequently the differences are established in terms of the results obtained instrumentally. However, sensory matching cannot be limited to rheological or optical measurements and must be related to the colour and thickness perceived.

The objectives of this work were (1) to determine instrumental colour and viscosity differences among commercial samples of vanilla milk beverages and vanilla soybean beverages, (2) to analyse whether there were perceptible differences between samples and up to what point these were related to the differences detected instrumentally and (3) to analyse whether the perceived differences influence consumer preferences.

2. MATERIALS AND METHODS

2.1. Samples

Six commercial samples, three vanilla milk beverages and three vanilla soymilk beverages, of different brands and characteristics were selected (Table 1). The selection criteria were based on analysis of product range and identification of leading market brands. The samples were purchased from the local market, taking into account expiration dates (the same for each brand), and stored at 4 ± 1ºC prior to testing. All measurements were performed within the declared shelf-life period of each sample.

Table 1. Ingredients and main characteristics of commercial milk and soymilk vanilla beverages samples.

Sample[a]	Main ingredients[b]	Hydrocolloid[b]	Dietary fibre[b] (g Kg^{-1})	Soluble solids (ºBrix)[c]	pH[c]
M1	Skimmed milk	Carrageenan Guar-gum	-	17.0 (0.07)	6.68 (0.06)
M2	Skimmed milk Dairy solids	-	-	14.7 (0.11)	6.82 (0.13)
M3	Semi-skimmed milk Dairy solids	Carrageenan	-	18.4 (0.11)	6.82 (0.02)
S1	Soybean	-	12	15.8 (0.04)	6.76 (0.13)
S2	Soybean	-	6	18.3 (0.04)	7.64 (0.03)
S3	Soybean	-	20	10.5 (0.06)	6.99 (0.05)

[a]Identification of sample commercial brands. Milk beverages: Central Lechera Asturiana (M1), Choleck (M2) and Okey (M3). Soymilk beverages: Bjorg (S1), Fit&Activ (S2) and Sojalia (S3).
[b]Declared on label.
[c]Average value of two samples, with standard deviations within parentheses.

2.2. Soluble solids and pH

Soluble solids were determined in an Atago RX-100 digital refractometer (Atago, Tokyo, Japan) at room temperature and the results expressed as ºBrix at 20ºC. A Crison GLP 21 digital pH meter (Crison Instruments SA, Barcelona, Spain) was used to measure pH at room temperature. Both measurements were taken in duplicate for each sample.

2.3. Colour measurements

Sample colour was measured in a Hunter Labscan II colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA). Samples were held in optical glass cells 3.8 cm high and 6 cm in diameter. A 3.5 cm thick sample layer was covered with a standard white plate (X = 78.50; Y = 83.32; Z = 87.94) for measurement of diffuse reflected light from the cell bottom using a 13 mm aperture. Reflection spectra were recorded and results were given in the CIELAB system for illuminant D65 and a 10º angle of vision. Registered parameters were: L^* (brightness), a^* (red component), b^* (yellow component), C^* (chroma) and h^* (hue). Two samples of each lot were measured in quadruplicate.

2.4. Flow measurements

Flow measurements were carried out in a Haake VT 550 viscometer using an NV double-gap sensor (radius ratio 1.02, length 60 mm, gap width 0.35 mm) and controlled by Rheowin Pro software (Thermo Haake, Karlsruhe, Germany). Flow curves were obtained by recording shear stress values (σ) when shearing the samples at increasing shear rates ($\dot{\gamma}$) from 1 to 600 s^{-1} with a ramp of 120 s. Two samples of each lot were measured in triplicate at a controlled temperature of 10 ± 1ºC using a Phoenix P1 Circulator device (Thermo Haake). This temperature was selected as representative of the usual consumption temperature for sensory analysis. A fresh sample was loaded for each measurement.

Experimental data were fitted to the Newton model equation ($\sigma = \eta\dot{\gamma}$) using Rheowin Pro Version 3.40 (Thermo, Haake).

2.5. Sensory evaluation

Two sensory methods were applied, a ranking test[13] and a consumer acceptability test. It was previously confirmed that both assessors and consumers had no allergies to milk or soy.

Forty assessors, with previous experience (>4 years) in evaluating sensory differences in dairy products using discriminant or ranking tests were recruited from IATA staff. They ranked the samples according to their yellow colour intensity (from light yellow to intense yellow), their brightness (from dark to bright) and their thickness, assessed in the mouth by swallowing (from thin to thick). Colour intensity and brightness were evaluated using a Colour Viewing Chamber equipped with illuminant D65 (ICS-Texicon España SA., Barcelona, Spain). Light from this source was projected vertically onto the sample and observed at an angle of 45º.[14] Thickness was assessed in a standardised test room with separate booths[15] under normal white fluorescent illumination. The six samples (30 mL) were served at 10 ± 1ºC in white plastic cups codified with random three-digit numbers and were presented simultaneously. For the evaluation of thickness the assessors were instructed to take each sample with a spoon (5 mL), hold it in their mouth for approximately 5s and then swallow it.

Colour and thickness were tested by 142 consumers for acceptability, using a nine-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”). The participants were selected according to the following criteria: age, gender and habitual consumers of milk beverages. Subjects were recruited by a local consumer association (AVACU) through a short questionnaire sent by mail. Of the 142, 61.2% were women, while 56.3% were under 30 years old, 25.4% were between 31 and 45 and 18.3% were over 45 years of age. They were given a brief overview of how the sensory test would be conducted. Each consumer evaluated the six samples in one session. The order of sample presentation was fixed across consumers according to a Williams design for six samples. To eliminate first-position bias, a seventh vanilla beverage sample, the same for each consumer, was evaluated first for all the serving orders as a dummy sample.[16] Samples (30 mL) at 10 ± 1ºC coded with random three-digit numbers were presented in white plastic cups monadically for colour and thickness acceptability evaluation.

Mineral water was provided for mouth-rinsing. Sessions were carried out between 11.00 and 13.00. Data acquisition was performed using Compusense® *five* release 4.6 software (Compusense Inc., Guelph, ON, Canada).

2.6. Statistical analysis

One-way analysis of variance (ANOVA) followed by Fisher's least significant difference (LSD) test ($\alpha \leq 0.05$) was applied to the instrumental data for both colour parameters and viscosity values in order to detect significant differences between samples. Principal Component Analysis (PCA) with varimax rotation was applied to the correlation matrix of the average values of colour parameters and viscosity using XLSTAT-Pro Version 2007 (Addinsoft, Paris, France). Friedman ANOVA was applied to the sensory data obtained in the ranking tests, and significance of differences between samples was determined by the Fisher test ($\alpha \leq 0.05$) using Compusense® software.

Two-way ANOVA was applied to both colour and thickness hedonic scores. Sources of variation were samples and consumers. Minimum significant differences were calculated by Fisher's LSD test ($\alpha \leq 0.05$) using XLSTAT-Pro software. An internal preference map was obtained for each of the two hedonic data matrices (colour and viscosity) using Senstools Version 3.3.2 (OP&P & Talcott, Utrecht, The Netherlands).

3. RESULTS AND DISCUSSION

3.1. Instrumental measurements

Reflectance spectra in the visible region (400-700 nm) obtained for the six vanilla beverages are shown in Fig. 1.

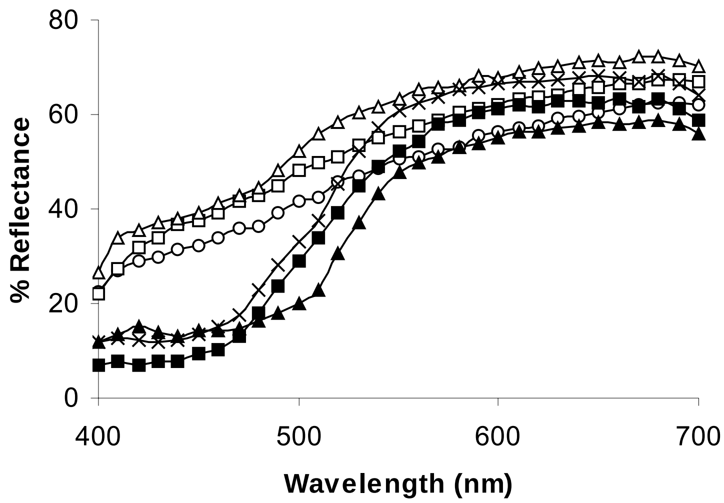

Figure 1. Spectral reflectance curves of milk and soymilk vanilla beverages: (■) M1, (▲) M2, (×) M3, (○) S1, (□) S2 and (△) S3. Identification of samples in Table 1.

All samples displayed the spectral curve typical of yellow-coloured materials, with maximum reflectance values at wavelengths around 580 nm, although clear differences were observed between the spectra of the milk samples (M1, M2 and M3) and those of the soymilk samples (S1, S2 and S3). The latter, with larger areas below the curves, indicated that the soymilk beverages were lighter in colour and not as yellow as the milk beverages. Significant differences (α = 0.05) in instrumental colour parameters values were detected between samples (Table 2). The greatest differences detected between the milk beverages and the soymilk beverages corresponded to yellowness (b^*) and saturation (C^*) values. The milk beverages, with values of b^* that ranged between 45.05 and 60.02, were perceived as yellower than the soymilk beverages (18.46 ≤ b^* ≤ 21.96). There was a wide range of redness values, due mainly to the highest value of a^* for sample M2 (9.85), which was yellow/orange in colour, and to the lowest value of a^* for sample S3 (0.63). Sample S3 was also the lightest in colour (L^* = 82.94) and sample M2 the darkest (L^* = 72.84).

The flow of all samples was Newtonian (R^2 ≥ 0.97), showing viscosity values in the range 4.34 - 7.92 mPa s (Table 2). Sample S3 had the highest viscosity and sample M2 the lowest. Significant differences (α = 0.05) in viscosity were detected among samples, although the differences in four of the six samples analysed were not very great (5.15 ≤ η ≤ 6.26 mPa s).

Table 2. Average values of instrumental colour parameters (*n* = 8) and viscosity (*n* = 6) for milk and soymilk vanilla beverages[a].

Sample[b]	*L**	*a**	*b**	*C**	*h**	*η* (mPa s)
M1	74.12ab	4.50d	60.02e	60.19e	85.72d	5.15b
M2	72.84a	9.85e	45.05c	46.12c	77.66a	4.34a
M3	78.35cd	2.40bc	54.12d	54.18d	87.46e	6.26c
S1	75.80bc	2.98c	19.47a	19.70ab	81.28b	5.69bc
S2	79.68d	1.88b	18.46a	18.56a	84.17c	6.19c
S3	82.94e	0.63a	21.96b	21.97b	88.36e	7.92d
Standard error[c]	0.87	0.31	0.67	0.67	0.33	0.23

[a]Values with different letters within a column are significantly different (α= 0.05).
[b]Identification of samples in Table 1.
[c]Standard error from ANOVA.

On applying PCA to the average values of both instrumental colour parameters and viscosity corresponding to the six samples, the first two components gave eigenvalues higher than 1. The first component accounted for 55.64% of the data variability, while up to 96.04% was explained by the first two components. The first component was associated with three colour parameters, *h** (*r* = 0.98), *L** (*r* = 0.85) and *a** (*r* = -0.90), and viscosity (*r* = 0.90) and clearly separated sample M2 on the left-hand side owing to its strong redness, lower brightness and lower viscosity. The second component was strongly associated with *b** (*r* = 0.99) and *C** (*r* = 0.99) (Fig. 2) and clearly separated the milk samples in the upper part owing to their strong yellowness.

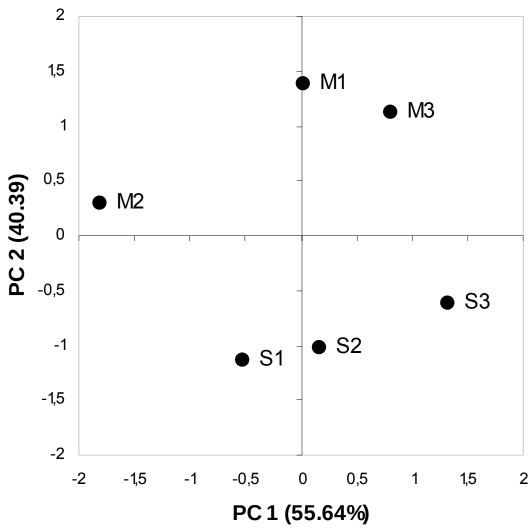

Figure 2. Principal component analysis plot for milk and soymilk vanilla beverages: instrumental colour parameters and viscosity. Identification of samples in Table 1.

3.2. Sensory analysis

Analysis of the results obtained from ranking tests revealed significant differences in yellow colour intensity, brightness and thickness among samples. Friedman *F* values were 150.01, 11.07 and 54.97 respectively (the theoretical *F* value being 11.07 for $\alpha = 0.05$). The vanilla milk samples were perceived as being yellower in colour than the vanilla soymilk samples and there were significant differences between them. No significant differences were perceived in soymilk samples yellowness (Fig. 3).

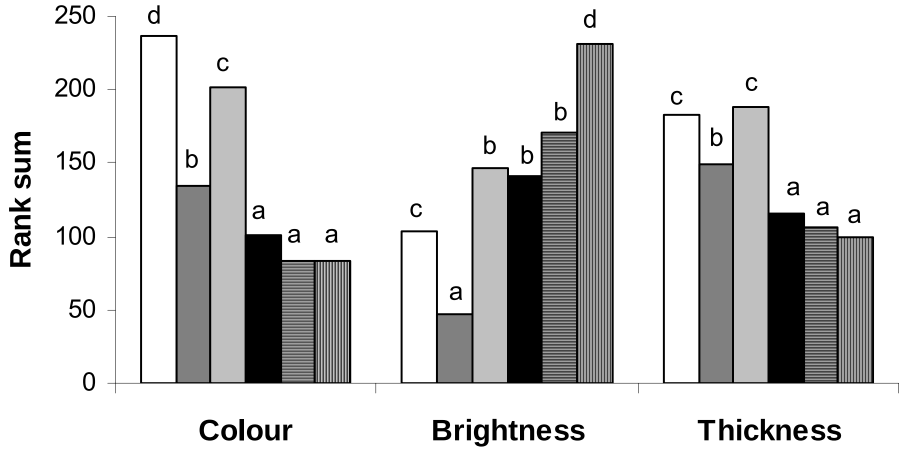

Figure 3. Sensory differences obtained by ranking test, from least intense to most intense, for colour, brightness and viscosity of milk and soymilk vanilla beverages ( ) M1, ( ) M2, ( ) M3, ( ) S1, ( ) S2 and ( ) S3. Different letters on top of bars indicate significant differences (α = 0.05). Identification of samples in Table 1.

The sensory differences between milk and soymilk samples were in agreement with the variation in b^* values (Table 2). Sample M2 was ranked as darker and sample S3 as brighter than the other samples in accordance with the corresponding L^* values (Table 2). No clear difference in brightness between milk and soymilk samples was detected (Fig. 3). In general, the perceived differences in sample colour were in agreement with the sample positions on the map obtained by PCA (Fig. 2).

On ranking sample thickness, significant differences between milk and soymilk samples were found. The latter were perceived as thinner, without significant differences existing between them. Two of the vanilla milk samples (M1 and M3) were perceived as thicker than the rest (Fig. 3). Considering all six samples together, a different trend between instrumental and sensory data can be observed (Table 2, Fig. 3). These results do not correspond to those expected according to the variation in viscosity values (Table 2), particularly if one takes into account the Newtonian character of the flow of all the analysed samples. In general, for fluid foods showing a Newtonian-type flow in which viscosity is independent of shear rate, the viscosity value is considered as the main physical stimulus responsible for human perception,[17] although the relationship between both types of variable can vary according, among other things, to the sensory procedure used to evaluate thickness and to the particular textural characteristics of the product. Valentova *et al.*[18] found that the correlation between instrumental viscosity and sensory viscosity assessed by slurping was higher than that obtained when it was evaluated by mouthfeeling or by swallowing. This fact seems logical if one bears in mind that, during ingestion and swallowing, the thickness perceived depends not only on the shear forces in the mouth but also on the effect of saliva, on mouth temperature and also on the other textural characteristics of the products. In the present case, close agreement was observed between the variation in instrumental viscosity values and the differences in perceived thickness when only milk samples were considered. The difference in thickness perceived between milk and soymilk samples could be due to the particular textural characteristics of either of the two food matrices**.** A similar influence of the textural characteristics on perceived thickness was found by Gallardo-Escamilla *et al.*[19] when they observed that equiviscous fermented whey beverages with different added hydrocolloids, were perceived as having different thicknesses. They also observed that the sample with added propylene glycol alginate, with a gritty mouthfeel, was perceived to be significantly less thick than the samples to which other hydrocolloids were added, which showed a smooth mouthfeel.

Colour acceptability data from all consumers were subjected to ANOVA, and significance of differences was established by the Fisher test (Table 3). The results indicated clear and significant differences in colour acceptability (F = 51.15, P < 0.001). The colour of milk samples, perceived as being yellower (Fig. 3) and with higher b^* values (Table 2), was clearly more acceptable than the colour of soymilk samples. Among milk samples, differences in acceptability were also related to the red component value. The highest a^* value corresponded to the lowest colour acceptability (Tables 2 and 3). A similar trend was observed in soymilk samples.

Table 3. Acceptability mean values[a] for colour of milk and soymilk vanilla beverages[b].

Sample[c]	All consumers (n = 142)	Subgroup I (n = 61)	Subgroup II (n = 57)	Subgroup III (n = 12)
M1	5.92d	5.54c	6.88c	4.92ab
M2	5.26c	6.41d	3.91a	4.00a
M3	6.77e	6.82d	7.16c	5.83bc
S1	4.00a	2.97a	3.98a	7.08d
S2	4.56b	3.77b	4.54b	6.75cd
S3	4.55b	3.70b	4.72b	6.83cd

[a]Values from 1 (“dislike extremely”) to 9 (“like extremely”).
[b]Values with different letters within a column are significantly different (α = 0.05).
[c]Identification of samples in Table 1.

The lowest acceptability score corresponded to sample S1 (average score = 4) with the highest *a** value (2.98). These results represent consumer colour preference in the population as a whole, assuming that all subjects exhibit similar preference patterns. An alternative approach to investigate hedonic information is to use multidimensional preference mapping techniques. In this case the matrix of individual acceptability scores across the six samples was analysed by internal preference mapping to obtain information about individual consumer preference as well as to identify consumer groups with different preference patterns. The amount of variance explained by the first two dimensions was 72% and the preference space defined by these dimensions is shown in Fig. 4.

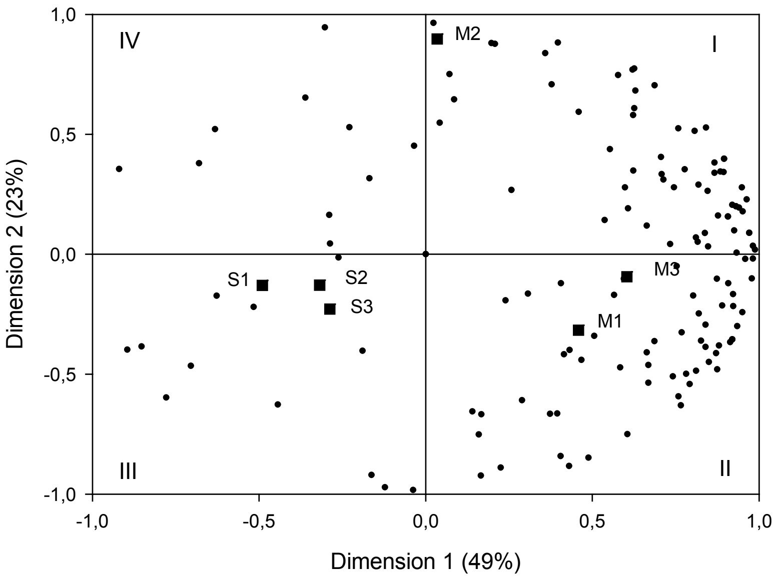

Figure 4. Internal preference map for colour acceptability of milk and soymilk vanilla beverages. Identification of samples in Table 1.

This space represents the consensus configuration of the six samples based on the colour acceptability data. Each point represents the end of each consumer's acceptance vector, and each vector can be visualized by drawing a line from the centre to the point, the length of vectors indicating how much the variance of the individual acceptability scores of consumers is explained by the plot dimensions. Points showing the preference direction for each consumer were mainly concentrated in the region of positive scores in dimension 1. Consumer population was segmented by similarity of preference using the quadrants defined by the two dimensions[20-22] (Fig. 4). One can observe that the main group of consumers (*n* = 61), referred to as subgroup I, is in the top right quadrant. This group preferred yellow- and yellow/orange-coloured samples (M1, M2, and M3), and the range of mean scores from 6.82 (sample M3) to 2.97 (sample S1) was wider than the range of scores for the whole population (Table 3). The second group of 57 consumers (subgroup II) is in the bottom right quadrant. They also preferred yellow-coloured samples (M1 and M3), although for this group the least preferred was the yellow/orange-coloured sample (M2). The group of consumers in the bottom left quadrant (subgroup III), with preference criteria opposed to those in subgroup I, represented less than 10% of consumers (*n* = 12) and preferred the lighter-coloured samples (S1, S2 and S3), and, as for the consumers in subgroup II, the yellow/orange-coloured sample was the least acceptable. Although these results indicate some differences in consumers colour preferences, they enable one to conclude that the majority of the people surveyed (83%, subgroups I and II) preferred the vanilla beverage samples to have a stronger yellow colour, although approximately half of them disliked slightly the colour of the product when it had an orange tinge.

Thickness acceptability data from all consumers were also subjected to ANOVA, and significance of differences was established by the Fisher test (Table 4).

Table 4. Acceptability mean values[a] for thickness of milk and soymilk vanilla beverages[b].

Sample	All consumers (n = 142)	Subgroup I (n = 58)	Subgroup II (n = 68)
M1	6.62cd	6.91c	6.56c
M2	6.33c	5.90b	6.91c
M3	6.77d	6.76c	6.96c
S1	4.77a	4.02a	5.06b
S2	5.28b	5.86b	4.59a
S3	4.99ab	5.46b	4.32a

[a]Values from 1 ("dislike extremely") to 9 ("like extremely").
[b]Values with different letters within a column are significantly different (α = 0.05).
[c]Identification of samples in Table 1.

The results indicated clear and significant differences in thickness acceptability (F = 60.11, P < 0.001). The thickness of milk samples was significantly more acceptable than that of soymilk samples. The differences in acceptability are not closely related to the differences in viscosity measured instrumentally (Table 2); however, they reveal clear agreement with the differences in thickness perceived sensorially (Fig. 3). This confirms that other factors influence the mouthfeel perception of thickness in conjunction with flow resistance of the fluid. Although in many cases there is a good relationship between the values of one or more rheological parameters and the sensorially perceived thickness,[23,24] rheological information may not be enough to explain all the differences perceived sensorially, particularly when products with different structural characteristics are being compared.[19,25] When the matrix of individual thickness acceptability was analysed by internal preference mapping, the total amount of variance explained by the first three dimensions was 78%. However, the preference criteria of most consumers could be adequately interpreted with only the first two dimensions, which explained 63% of the total variance. The preference space defined by these dimensions is shown in Fig. 5.

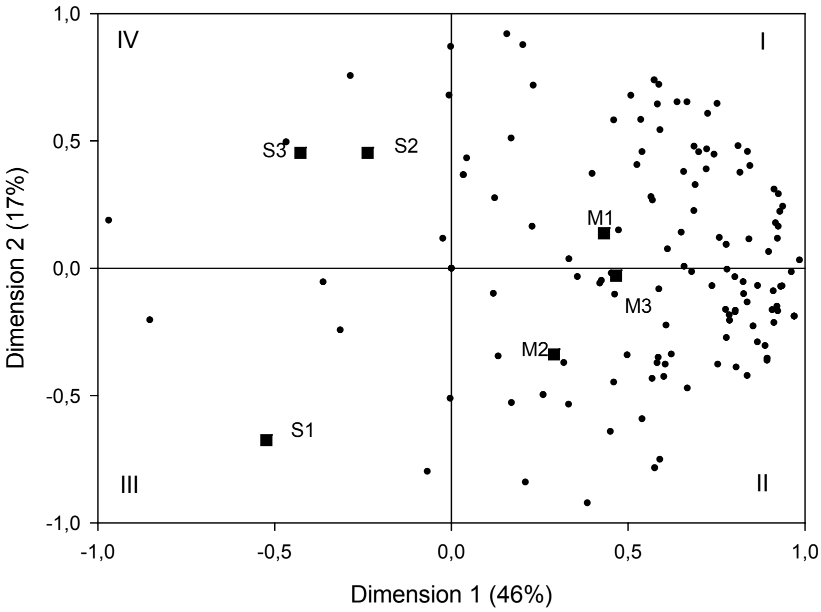

Figure 5. Internal preference map for thickness acceptability of milk and soymilk vanilla beverages. Identification of samples in Table 1.

One can observe that practically all consumers fall within the right-hand part of the preference space; about 41% fall within the top right quadrant, while approximately 48% are placed in the bottom right-hand quadrant. This last group of consumers (subgroup II, *n* = 68) clearly preferred the thickness of milk samples, and the differences perceived in the magnitude of this attribute (Fig. 3) had no influence on its acceptability. In general, consumers in subgroup I (*n* = 58) also preferred the thickness of milk samples, but in this case they were influenced by the differences in sensorially perceived thickness (Fig. 3) and significantly preferred the more viscous samples (M1 and M3).

4. CONCLUSIONS

In the samples of milk and soymilk vanilla beverages studied, there is good agreement between the variations in the values of the parameters *L**, *a** and *b** and the differences in the sensorially perceived colour. These differences significantly influenced the acceptability of the samples according to colour. The joint consideration of the instrumental values of the different parameters, especially of *L**, *b** and *a**, allows reasonably good prediction of the perceptible differences in the colour of these products and explains the differences in consumer preferences in terms of this attribute. By contrast, the same does not occur for Newtonian viscosity, which does not show a similar variation trend to that observed for perceived thickness in ranking evaluation or to that observed in the consumer acceptance test. This confirms that factors other than flow resistance can also influence the mouthfeel perception of viscosity and that, to obtain products of similar thickness, rheological information alone is not enough; rather, they must be assessed sensorially. In order to design an effective procedure to improve the thickness of soymilk beverages, a more in-depth study is required to analyse and identify the physicochemical and structural characteristics that are responsible for the perceived differences in this characteristic.

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CAPÍTULO 2

ACCEPTABILITY OF MILK AND SOYMILK VANILLA BEVERAGES. DEMOGRAPHICS, CONSUMPTION FREQUENCY AND SENSORY ASPECTS

Beatriz Villegas, Inmaculada Carbonell and Elvira Costell

Food Science and Technology International, enviado

ABSTRACT

Acceptance of food is basically the result of the interaction between food and human and it depends not only on the product's characteristics but also on those of each consumer. The main objective of this work is to analyse how the acceptability of milk and soymilk vanilla beverages is influenced by demographic characteristics, consumer habits and individual preferences and the sensorial properties of both products. Six commercial samples, comprising three milk beverages and three soymilk beverages of different brands and characteristics, were evaluated sensorially. Overall acceptability was tested by 142 consumers, using a 9-point hedonic scale and 36 assessors ranked the samples from the least to the most intense according to their yellow colour, brightness, vanilla flavour intensity, sweetness and thickness. The milk samples were significantly ($P < 0.05$) more acceptable than the soymilk ones and were perceived as being stronger yellow and less light in colour, with a more intense sweetness, stronger vanilla flavour and thicker consistency. The results obtained lead us to the conclusion that the difference in acceptability between milk and soymilk beverages is more closely related to their sensorial attributes than to other characteristics (demographic, consumer habits and individual preferences) of the consumer population surveyed.

Keywords: vanilla beverages, soybean, milk, acceptability

1. INTRODUCTION

Soybean is an important protein source, a potential source of bioactive peptides and contains high levels of minerals and amino-acids (Hayta *et al*., 2003; Wang and de Mejía, 2005). Soymilk is one of the more popular soybean products, with plain and vanilla being the most common flavours, although these beverages are being developed in a wide variety of other flavours (Chambers *et al*., 2006). Soymilk and soymilk beverage consumption affords well-known health benefits (Hasler, 1998) and can also be an interesting alternative for consumers who are lactose intolerant, allergic to milk or avoid milk for any other reason (Reilly *et al.*, 2006). The main problems facing the acceptance of soymilk and soymilk beverages is that their sensory characteristics do not match those of milk and milk beverages, and that from the consumer's viewpoint, health is important but not at the expense of sensory quality (N'Kouka *et al.*, 2004; Deshpande *et al.*, 2005).

Some authors have described the presence of undesirable characteristics in the texture of these beverages, for instance chalky, dry, oily (N'Kouka *et al.*, 2004; Deshpande *et al.*, 2005; Potter *et al.*, 2007). In spite of the importance of textural characteristics, the main factor limiting the consumption of soymilk products is related to their flavour, commonly being referred to as "beany", although more specific descriptions have been developed by sensory descriptive analyses of these products (Torres-Peñaranda and Reitmeier, 2001; N'Kouka *et al.*, 2004; Chambers *et al.*, 2006). This beany flavour has been attributed to degradation products of polyunsaturated fatty acids induced by lipoxygenase enzyme (Keast and Lau, 2006). Consequently, one approach attempting to solve the flavour problem was to develop soy varieties with lower lipoxygenase content, in order to diminish the degree of fatty acid oxidation during the soymilk manufacturing process; however, results so far are not completely satisfactory (Yuan and Chang, 2007). Another approach to solve the undesirable flavour of soymilk involves trying to mask soy flavour by designing beverages with different flavourings, like vanilla, chocolate or almond flavour (Wang *et al.*, 2001) or adding other ingredients. For instance, Deshpande *et al.* (2005) compared the sensory acceptability of chocolate-flavoured peanut-soy beverages with a commercial milkshake, obtaining beverages with significantly higher ratings for appearance, colour and sweetness, but not for overall liking when compared to the control. Also, Mepba *et al.* (2006) formulated coco-soy beverages, which were significantly less acceptable when compared to the milk control sample. Potter *et al.* (2007) formulated soy beverages containing wild blueberry and different soy protein ingredients to study which sensory attributes were related to overall acceptability of the product, and they found flavour attributes were the most closely related in the case of wild blueberry-soy acceptability.

Currently there are few or no data comparing the acceptability of commercial milk and soymilk beverages. It is clear that a consumer's final response is based on the perception of the different attributes that make up the sensorial quality of a product as a whole. Apart from the characteristics of food and the sensations that consumers can experience when ingesting it, the attitude and opinion of each consumer regarding the nutritional characteristics or the composition of the product, condition the consumers' choice when purchasing and may modify the degree of pleasure when consuming it (Barrios and Costell, 2004).

To increase the acceptability of soymilk beverages one must gain a better understanding of their chemical, physical and sensorial characteristics and how each of these influences the consumer's final response.

The objectives of this work were: 1) to analyse the differences in acceptability between commercial vanilla-flavoured milk and soymilk beverages; 2) to study how acceptability is influenced by demographic characteristics, consumer habits and individual preferences; 3) to analyse the relationship between acceptability and the sensorial differences perceived between samples.

2. MATERIALS AND METHODS

2.1. Samples

Six commercial samples, comprising three vanilla milk beverages and three vanilla soymilk beverages, of different brands and characteristics were selected (Table 1). The selection criteria were based on analysis of product range and identification of leading market brands. The samples were purchased from the local supermarket taking into account expiration dates (the same for each brand) and were stored at 4 ± 1ºC prior to testing. All measurements were performed within the declared shelf-life period of each sample.

Table 1. Ingredients and main characteristics of commercial milk and soymilk vanilla beverages samples.

Sample[a]	Main ingredients[b]	Hydrocolloid[b]	Dietary fibre[b] (g Kg^{-1})	Soluble solids (ºBrix)[c]	pH[c]
M1	Skimmed milk	Carrageenan Guar-gum	-	17.0 (0.07)	6.68 (0.06)
M2	Skimmed milk Dairy solids	-	-	14.7 (0.11)	6.82 (0.13)
M3	Semi-skimmed milk Dairy solids	Carrageenan	-	18.4 (0.11)	6.82 (0.02)
S1	Soybean	-	12	15.8 (0.04)	6.76 (0.13)
S2	Soybean	-	6	18.3 (0.04)	7.64 (0.03)
S3	Soybean	-	20	10.5 (0.06)	6.99 (0.05)

[a]Milk beverages: M1, M2 and M3. Soymilk beverages: S1; S2 and S3.
[b]Declared in label.
[c]Average value of two samples. Standard deviations within parenthesis.

2.2. Soluble solids and pH

Soluble solids were determined in a digital refractometer ATAGO RX-100 (Atago Co. Ltd. Tokio, Japan) at room temperature and the results expressed as degrees Brix at 20ºC. A digital pH meter GLP 21, Crison (Crison Instruments SA. Barcelona, Spain) was used to measure pH at room temperature. Both measurements were taken in duplicate for each sample.

2.3. Sensory evaluation

Two sensory methods were applied: a consumer acceptability test and a ranking test (ISO, 2006). It was previously confirmed that both consumers and assessors had no allergies to milk or soy.

Overall acceptability was tested by 142 consumers, using a 9-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”). The participants were selected according to the following criteria: age, gender and habitual consumers of milk and/or vegetable beverages. Consumers were recruited by a local consumer association (AVACU) through a short questionnaire sent by mail. Some demographic and sociological characteristics of consumers are shown in Table 2. They were given a brief overview of how the sensory test would be conducted and they filled in a brief questionnaire about their knowledge and consumer habits with respect to milk and vegetable beverages. Each consumer evaluated the six samples in one session. The order of sample presentation was fixed across consumers according to a Williams design for six samples in balanced blocks of six consumers (MacFie *et al.*, 1989). To eliminate the first position bias, a seventh vanilla beverage sample, the same for each consumer, was evaluated first for all the serving orders as a dummy sample (Lange *et al.*, 1999). The samples (30 mL) were served at 10 ± 1ºC, in white plastic cups codified with three-digit random numbers and were presented monadically for overall acceptability evaluation.

Table 2. Demographic and sociological characteristics of consumers (n = 142).

Characteristics	Category	Number of consumers	Percentage (%)
Gender	Women	87	61.2
	Men	55	38.8
Age group	18-30	80	56.3
	31-45	36	25.4
	>45	26	18.3
Marital status	Single	90	63.4
	Married	46	32.4
	Others	6	4.2
Occupation	Employee	84	59.2
	Student	50	35.2
	Housewife	3	2.1
	Unemployed	5	3.5
Education	Primary studies	8	5.6
	High school certificate	37	26.1
	Senior technician	16	11.3
	University degree	81	57.0

Differences in perception of yellow colour, brightness, vanilla flavour intensity, sweetness and thickness among the six samples evaluated (three vanilla milk beverages and three vanilla soymilk beverages) were analysed using a ranking test (ISO, 2006; Meilgaard *et al.*, 1999) by thirty-six assessors with previous experience (more than four years) in evaluating sensory differences in dairy products. The assessors were previously selected according to their taste sensitivity and their capacity to detect differences in intensities of the above mentioned attributes (ISO, 1993). First, they ranked the six samples from the least to the most intense according to their yellow colour and to their brightness by observing the samples in a Colour Viewing Chamber equipped with illuminant D65 (ICS-Texicon España SA. Barcelona, Spain). Light from this source was projected vertically onto the sample and observed at an angle of 45º (ISO, 1999). Secondly, the assessors ranked the samples from the least to the most intense according to their vanilla flavour intensity, sweetness and thickness in separate booths in a standardized test room (ISO, 1988). As in the acceptability evaluation, the samples were served at 10 ± 1ºC, in white plastic cups codified with three-digit random numbers although in this case they were presented simultaneously to the assessors.

In both types of test, mineral water was provided for mouth-rinsing. Sessions were carried out in the morning (11.00 - 13.00). Data acquisition was performed using Compusense® *five* release 4.6 software (Compusense Inc., Guelph, Ontario, Canada).

2.4. Statistical analysis

Two-way Analysis of Variance (ANOVA), with sample and consumer being sources of variation, was applied to the overall acceptability data. Significance of differences between samples was determined by Fisher test ($\alpha \leq 0.05$) using XLSTAT-Pro software v. 2007 (Addinsoft, France). The Taguchi's signal-to-noise ratio (SNR) (Equation 1) was calculated in order to know the robustness of acceptability mean values of samples (Gacula, 1993; Gacula *et al.*, 2007; Pastor *et al.*, 1996),

$$SNR = -10\log\left[(1/\bar{y})(3s^2/\bar{y}^2)\right] \qquad (1)$$

where $\bar{y}$ and s^2 are sample mean and sample variance, respectively.

To study the influence of gender, age and soymilk consumption on the acceptability data, three independent two-way analyses of variance with interaction were applied.

Minimum significant differences were calculated by Fisher's LSD ($\alpha \leq 0.05$) XLSTAT-Pro software.
Internal preference map was obtained for the overall acceptability data matrix using Senstools v. 3.3.2 (OP&P & Talcott, Utrecht, The Netherlands).

Friedman Analysis of Variance was applied to the sensory data obtained in the ranking tests, significance of differences between samples were determined by the Fisher test ($\alpha \leq 0.05$) using Compusense software. Kendall's concordance coefficient (Equation 2) was calculated (Moskowitz, 1983), in order to measure how well the group, in general, agreed with the final ranking:

$$W = \frac{12S}{K^2(N^3 - N)} \quad (2)$$

where S is the sum of squares of the observed deviations from the mean of the ranked totals, K is the number of assessors, and N the number of samples ranked.
Principal Component Analysis (PCA) with varimax rotation was applied to the correlation matrix of the ranking sum values of sensory attributes using XLSTAT-Pro software.

In order to study the relationship between acceptability and sensory data, regression analyses were carried out between the values of the rank sum of each sensorial attribute and the coordinates of the samples in the first two dimensions of the internal preference map. Regression coefficients were calculated by using the PROFIT program of the PC-MDS Multidimensional Statistic Package v 5.1 software (Smith, 1990).

3. RESULTS AND DISCUSSION

3.1. Overall acceptability

Generally speaking, and as expected, the consumers surveyed knew more about the milk beverages than the vegetable ones (Figure 1).

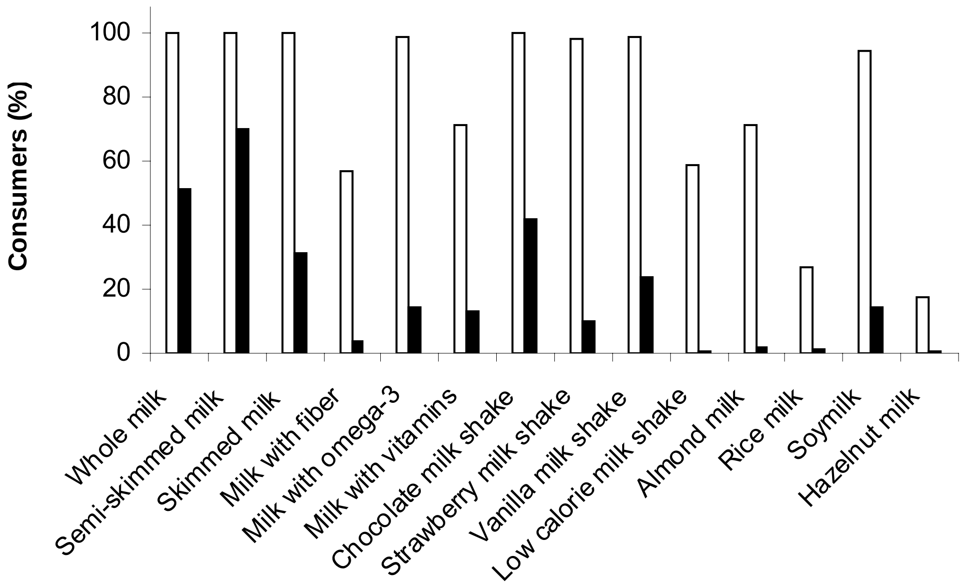

Figure 1. Knowledge (☐) and last month consumption (■) of different milk and vegetable beverages to the surveyed population (n = 142).

Among the vegetable beverages included in the survey, the best known was soymilk at 94.4% followed by almond milk, while only 26.8% of the consumers stated that they had heard of rice milk and an even smaller percentage (17.6%) of hazelnut milk. With respect to the consumption of each of these products in the previous month, semi-skimmed milk registered the highest consumption, followed by whole and skimmed milk (Figure 1). It is worth pointing out the high consumption of chocolate milkshake, intermediate between whole milk and skimmed milk. The vegetable beverage with highest consumption was soymilk, although the corresponding percentage was 14%, clearly much lower than the milk beverages.

The results obtained were subjected to analysis of variance which revealed significant differences in the acceptability of the different samples (F = 133.99, P < 0.0001). The milk samples were clearly and significantly more acceptable than the soymilk ones (Table 3), with acceptability values greater than 6 ("like slightly") compared to those below 4 ("dislike slightly") corresponding to the soymilk beverages.

Table 3. Overall acceptability mean values[a,b] (n = 142) and signal-to-noise ratio (SNR) values of milk and soymilk vanilla beverages.

Sample[c]	M1	M2	M3	S1	S2	S3
Overall acceptability	6.6 a	6.1 b	6.7 a	3.1 d	4.0 c	3.4 d
SNR	15.7	14.8	15.8	6.2	9.4	7.4

[a]From ANOVA, values with different letters are significantly different (α = 0.05).
[b]Values from 1 "dislike extremely" to 9 "like extremely".
[c]Identification of samples in Table 1.

Evaluating a product's degree of acceptability by just considering the average values obtained from the individual consumer's assessment, can lead to erroneous conclusions. Often, this average value does not give information about the real acceptability of the product; rather it is the result of considering a series of opinions together that are more or less divergent. The lower the variability of the individual data, the better the mean value of the population represents the degree of real acceptability of the sample. The calculation of the Taguchi SNR index (signal-to-noise ratio) enables complementary information to be obtained regarding the robustness of the mean value of acceptability of each sample. For instance, in this case, the result of the ANOVA (Table 3) indicated that the samples M1 and M3 were equally acceptable. The almost identical values of the SNR index for these samples (15.7 and 15.8, respectively) indicated that the variability of the individual data of acceptability was also similar for both samples. However, although significant differences in acceptability were not detected between samples S1 and S3, the SNR index values (6.2 and 7.4, respectively) made apparent the lower extent of coincidence between the individual data for acceptability of sample S1 as compared to that recorded for sample S3. Even with this complementary information, the mean acceptability values do not always accurately reflect the opinion of the population surveyed because, frequently, not all the consumers have homogeneous acceptability criteria. Analysing the opinion of the different groups of consumers based on demographic criteria, in terms of their consumer habits or according to individual preferences, can afford more complete information about the real acceptability of the products under evaluation.

3.2. Influence of demographic characteristics, consumer habits and individual preferences on acceptability

The differences between men and women with respect to sample acceptability were not significant (P = 0.053, Table 4).

Table 4. Two way analyses of variance with interactions for overall acceptability data.

Factors	Source	*F*-ratio	*P*-value
Gender and sample	Gender	3.77	0.053
	Sample	107.08	< 0.0001
	Gender*sample	1.23	0.292
Age and sample	Age	0.51	0.602
	Sample	79.79	< 0.0001
	Age*sample	2.45	0.007
Consumption of soymilk and sample	Consumption	6.00	0.014
	Sample	40.21	< 0.0001
	Consumption*sample	3.59	0.003
Subgroup of consumer[a] and sample	Subgroup of consumer	3.63	0.057
	Sample	105.70	< 0.0001
	Subgroup*sample	1.54	0.175

[a]From internal preference map.

Only one of the soymilk beverages (sample S2) was significantly more acceptable (α = 0.05) for men than for women (Table 5). As far as age was concerned, a significant effect was detected in the interaction between this factor and the samples in terms of acceptability. This showed that differences do exist in the acceptability criteria of consumers of different ages (Table 4). Although the milk samples were significantly more acceptable than the soymilk ones for the whole population under survey, the greatest differences in acceptability were detected between extreme age groups. The youngest consumers (18-30 years) considered the milk sample M3 to be more acceptable and the soymilk beverages S2 and S3 less acceptable than the older consumers (Table 5).

Table 5. Influence of different factors (gender, age, soymilk consumption and preference) on acceptability[a,b] of milk and soymilk vanilla beverages.

Sample[c]	Gender		Age			Soymilk consumption		Preference map	
	Women	Men	G1 (18-30)	G2 (31-45)	G3 (>45)	No consumers	Consumers	Subgroup I	Subgroup II
M1	6.5 abc	6.9 a	6.9 a	6.4 ab	6.3 ab	6.6 ab	6.5 abc	6.7 a	6.5 ab
M2	6.3 bc	6.0 c	6.2 b	6.0 b	6.1 b	6.2 bc	5.6 cd	6.0 b	6.3 ab
M3	6.6 abc	6.9 ab	7.1 a	6.4 ab	6.0 b	6.7 a	6.5 abc	6.6 ab	6.7 a
S1	3.0 f	3.3 ef	3.2 ef	2.8 f	3.4 def	3.0 h	4.0 fg	3.5 d	2.7 e
S2	3.7 e	4.5 d	3.6 de	4.5 c	4.5 c	3.8 fg	5.3 de	4.3 c	3.7 d
S3	3.4 ef	3.4 ef	3.2 ef	3.3 def	4.1 cd	3.2 gh	4.3 ef	3.4 d	3.3 de

[a]For each factor (gender, age, soymilk consumption and preference) values within a column and/or a row with different letters from each one of the ANOVAs are significantly different (α = 0.05).
[b]Values from 1 “dislike extremely” to 9 “like extremely”.
[c]Identification of samples in Table 1.

On analysing the differences in sample acceptability between the consumers and non-consumers of soymilk, a significant effect was found in the interaction between this consumer habit and sample acceptability (Table 4). However, differences were not detected in the acceptability of the milk samples between consumers and non-consumers of soymilk. The soymilk consumers awarded significantly higher acceptability values to this type of beverage, and even found one of the soymilk samples (S2) as acceptable as milk sample M2 (Table 5). This would seem to confirm that habitual consumption of a food increases its acceptability. To this effect, Luckow *et al.* (2005) observed a significant increase in the acceptability of a series of probiotic beverages after they had been consumed daily for a week; and Stein *et al.* (2003) found a positive correlation between familiarity and the level of liking in a study on the acceptance of bitter beverages.

To obtain information about individual consumer preference, as well as to identify consumer groups with different preference patterns, the matrix of individual acceptability scores across the six samples was analysed by Internal Preference Mapping. The amount of variance explained by the first two dimensions was 74% and the preference space defined by these dimensions is shown in Figure 2. This space represents the consensus configuration of the six samples based on the overall acceptability data. Each point represents the end of each consumer's acceptance vector and each vector can be visualized by drawing a line from the centre to the point, the length of vectors indicating to what extent the variance of the consumers' individual acceptability scores is explained by the dimensions of the plot. Points showing the preference direction for each consumer were mainly concentrated in the region of positive scores in dimension 1. Consumer population was segmented by similarity of preference using the quadrants defined by the two dimensions (Greenhoff and MacFie, 1994; Damasio *et al.*, 1999; Costell *et al.*, 2000).

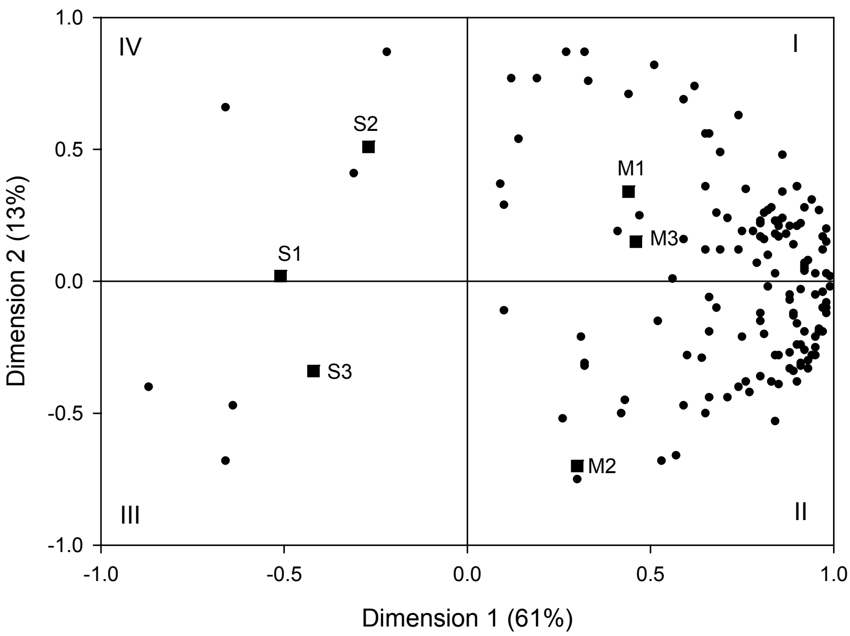

Figure 2. Internal preference map for overall acceptability of milk and soymilk vanilla beverages. Identification of samples in Table 1.

Ninety-six percent (96%) of consumers are located in the right-hand side of the map, constituting two subgroups in terms of their position in the upper part (subgroup I, *n* = 69) or at the bottom of the diagram (subgroup II, *n* = 67). The difference between sample acceptability for both subgroups of consumers was not significant (*P* = 0.057, Table 4). The consumers in subgroup I significantly assessed the soymilk beverages as more acceptable than those in subgroup II (Table 5) although, the acceptability of these beverages did not obtain a 5-point qualification in any case ("neither like nor dislike"), while the acceptability of the milk beverages oscillated between 6 and 6.7 ("like slightly").

3.3. Relationship between acceptability and the sensorial differences among samples

The Friedman analysis of variance of the results of the ranking tests indicated that there were significant differences between samples for all the attributes evaluated (Table 6). The milk samples were perceived as being more intense and less light in colour, with a stronger vanilla flavour and more intense sweetness and thicker consistency (Table 7).

Table 6. Friedman value[a] and Kendall's concordance coefficient for the sensory attributes evaluated by ranking test.

Sensory attribute	Friedman value (F)	Kendall's coefficient (W)
Color	135.34	0.75
Darkness	129.22	0.72
Vanilla	121.44	0.67
Sweetness	132.01	0.73
Thickness	76.34	0.42

[a]Theoretical F value being 11.07 for α = 0.05.

Table 7. Total rank sum for the different sensory attributes for milk and soymilk vanilla beverages[a].

Sample[b]	Color	Brightness	Vanilla flavor	Sweetness	Thickness
M1	213 a	88 d	184 a	180 a	174 a
M2	121 c	43 e	163 a	138 b	139 b
M3	181 b	126 c	175 a	195 a	177 a
S1	91 cd	132 bc	76 bc	74 c	102 c
S2	73 d	158 b	104 b	121 b	89 c
S3	77 d	209 a	54 c	48 c	75 c

[a]Values within a column with different letters are significantly different (α = 0.05).
[b]Identification of samples in Table 1.

According to the values of the Kendall concordance coefficient (Table 6), the tasters displayed good concordance in their assessment of the perceptible differences between samples, except for thickness, for which the coefficient was somewhat lower.

A Principal Component Analysis was applied to the values of the rank sums of the assessed attributes. The three first components explained 99.3% of the variance (Figure 3). The first component was mainly associated to colour (r = 0.89) and thickness (r = 0.76, Table 8), separating the samples M1 and M3 on the right-hand side of the plot, because they are the yellowest and most viscous samples. The second component was strongly associated to the light colour of the samples (r = 0.94), separating sample M2 from the rest, for being the darkest of all. The third component clearly separated sample S2 from the other soymilk samples. This component was fundamentally associated to flavour aspects. According to its position on the plot, sample S2 (Table 7) was the most similar in terms of vanilla flavour and sweetness intensity to the milk samples (M1, M2 and M3). This coincides with the value obtained for the measurement of soluble solids (ºBrix) of sample S2 (18.3 %), which was higher than that of the other soymilk samples and similar to samples M1 and M3 (Table 1).

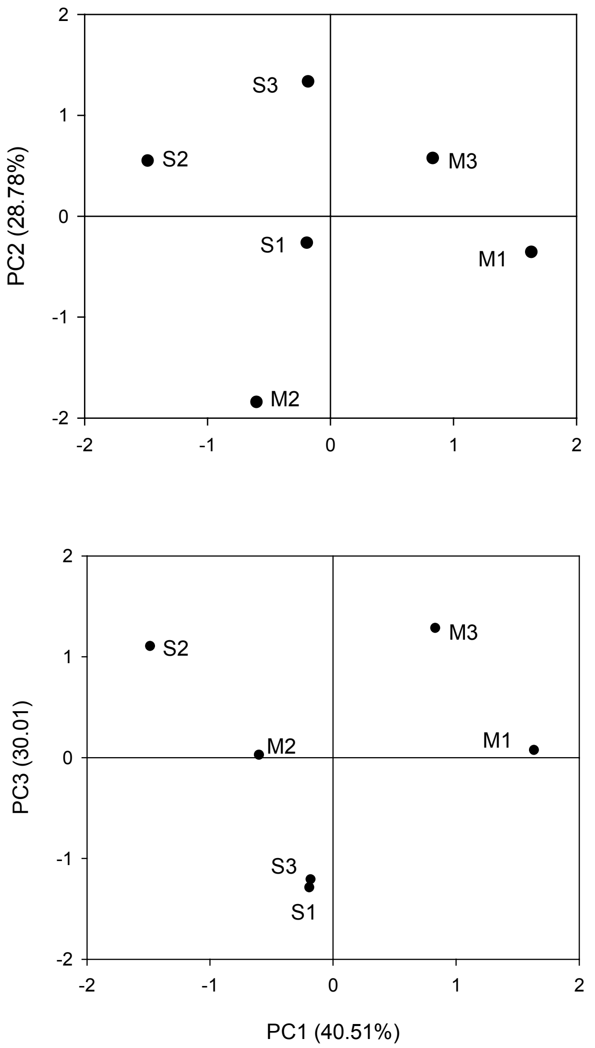

Figure 3. Principal component analysis plot for milk and soymilk vanilla beverages. Identification of samples in Table 1.

Table 8. Factor loadings for principal components (PC1 to PC3) obtained by varimax rotation for attribute total rank sums and percentage of variance explained by each one of the components.

PCA	PC1	PC2	PC3
Color	0.89	-0.24	0.38
Brightness	-0.24	0.94	-0.25
Vanilla	0.56	-0.51	0.65
Sweetness	0.54	-0.30	0.79
Thickness	0.76	-0.39	0.50
% Variance	40.51	28.77	30.01
% Cumulative variance	40.51	69.28	99.30

On studying the relationship between the main dimensions of the internal preference map (Figure 2) and the difference in intensity of the sensorial traits analysed (Table 7), one can observe that the milk samples were a stronger yellow in colour, with a stronger vanilla flavour, sweeter and more viscous than the soymilk beverages (Figure 4). The fact that one of the soymilk samples (S2) was more acceptable than the other two (Table 3), could be related to its more intense vanilla flavour and sweetness (Table 7). These results coincide with those obtained by Wang *et al*. (2001), who observed that sweeteners were necessary to enhance palatability and that the addition of different flavouring agents slightly improved the acceptance of soymilk beverages.

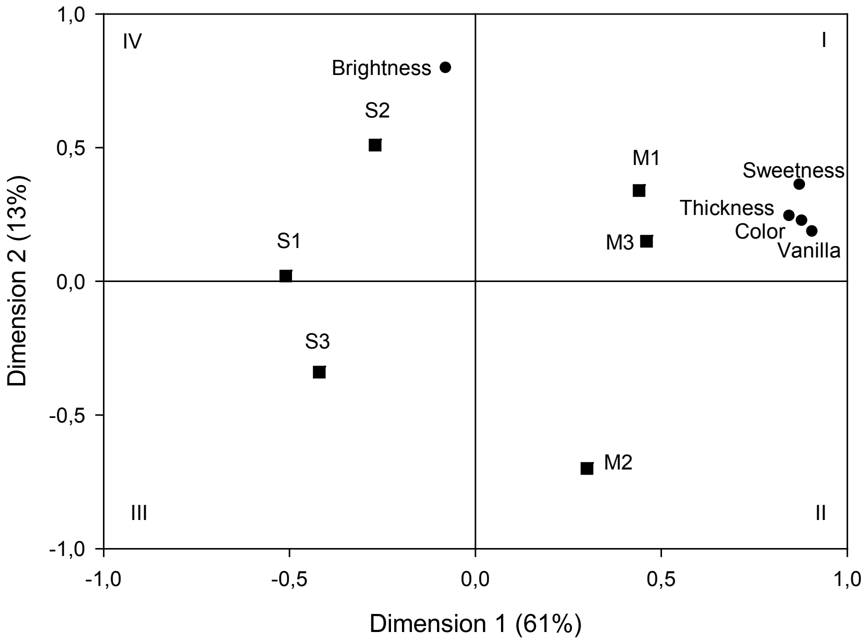

Figure 4. Consumer's preferences of milk and soymilk vanilla beverages in relation to sensory attributes. Identification of samples in Table 1.

4. CONCLUSIONS

The results obtained led us to conclude that there is a clear difference between the acceptability of the vanilla-flavoured milk and that of soymilk beverages. Moreover, they indicated that this difference was more closely related to the sensorial aspects of both types of beverages than to other characteristics (demographic, consumer habits and individual preferences) of the consumer population surveyed.

The results also indicated that, despite the problems related to its particular flavour, it would be possible to improve the acceptability of the vanilla-flavoured soymilk beverages by modifying their formulation to obtain sweeter and more viscous products, with a stronger vanilla flavour. It is necessary to carry out a more in-depth study of the concentration of each ingredient needed to modify the sensorially perceived colour, flavour and viscosity of these products, without forgetting to analyse the possible effect that interactions between the different ingredients can have on the sensorial quality of the final product.

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CAPÍTULO 3

EFFECTS OF PRODUCT INFORMATION AND CONSUMER ATTITUDES ON RESPONSES TO MILK AND SOYBEAN VANILLA BEVERAGES

Beatriz Villegas, Inmaculada Carbonell and Elvira Costell

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ABSTRACT

BACKGROUND: A study was made into how the type of information (picture of real package or card with beverage type and nutritional facts) and consumer attitudes (interest in eating healthily and food neophobia) affect hedonic ratings and purchase intention with respect to milk and soybean vanilla beverages and to what extent the expectations created by information influence the hedonic ratings of these products.

RESULTS: A significant effect of the interaction between samples and information type was detected for both expected acceptability and purchase intention when only information about the samples was provided. The effect of this interaction was significant for acceptability ratings when the samples were evaluated together with corresponding information. The acceptability and purchase intention for two soymilk samples were significantly higher for consumers interested in eating healthily. Both types of information generated an assimilation effect for four samples; however only for milk beverages this effect was complete.

CONCLUSION: Information affected purchase intention to a greater extent than hedonic ratings. The type of information significantly affected hedonic ratings in most samples, although sensory quality seemed more decisive for two of the soymilk samples. The extent to which information influenced consumer behaviour was also dependent on some consumer attitudes, like the interest in eating healthily.

Keywords: hedonic response, consumer attitudes, product information, vanilla beverages, milk, soybean

1. INTRODUCTION

Consumers' response to foods depends on the interaction of several factors that are different in nature.[1,2] In addition to the characteristics of the food itself and the sensations the consumer experiences when ingesting it, there are other influential factors, such as the opinion each consumer has of the nutritional characteristics or the composition of the product,[3] its safety[4] and, even, its trade name[5] or price.[6,7] All these factors can influence their choice at the moment of purchase and modify the degree of pleasure they experience when consuming it. This fact is of particular importance in the acceptance or rejection of some types of foods, like functional or "healthy" foods, which the consumer sees as a possible alternative to conventional foods.[8-10] In a simplify manner, consumer response to a product is mainly defined by: 1) a cognitive component, coming from the knowledge and opinions about a product; 2) an affective component, responsible for positive or negative feelings towards a product and 3) a behavioural component, involving intentions or actions, defining how willing a consumer is to do something in certain situations. The cognitive component is related to the information that a person has about an object, the affective component summarizes the general feelings of a person about a product and the component relative to an action or intention (behavioural), reflects the intentions of a person about his/her future behaviour.[11]

When consumers eat food, their responses are not only based on the sensory characteristics of the product but are also related to other factors, such as information acquired about a product, past experience and their attitudes and beliefs.[12,13] Consumers' expectations, be they sensory or hedonic, play an important role in food selection and consumption. Subsequent confirmation or disconformation can lead to either repeated consumption or rejection of a product. To explain how disconfirmation created by expectations may influence product acceptance four models, based on four psychological theories, have been proposed: Assimilation, Contrast, Generalized negativity and Assimilation-contrast.[14-16] Among them, assimilation (actual liking moves in the direction of expected liking) and contrast (actual liking moves in the opossite direction from expectation) models were observed in a number of previous studies on different types of food products.[17-21]

The main focus of the current work concerns how expectations generated by information type affect hedonic ratings and the purchase intention of milk and soybean vanilla beverages. The study also explores the influence exerted by certain consumer attitudes and beliefs. These products were chosen for a number of reasons: soymilk and soybean-beverage consumption affords well-known health benefits[22,23] and can also be an interesting alternative for consumers who are lactose intolerant, allergic to milk or avoid milk for any other reasons.[24] However, in general, consumers find them less acceptable than milk beverages. In a preliminary study (Villegas B, unpublished) it was showed that there was a clear difference between the acceptability of vanilla-flavoured milk and soymilk beverages. Moreover, they indicated that this difference was more closely related to the sensorial properties of both types of beverage than to other characteristics (demographic, consumer habits and individual preferences) in the consumer population surveyed. These results are in agreement with other authors who have pointed out that one of the problems facing the acceptance of soymilk and soymilk beverages is that their sensory characteristics do not match those of milk and milk beverages.[25-27] Given this situation, it is of interest to explore the possible influence information (product image or nutritional facts) has on the acceptability of these products.

Currently there is little information available about the possible influence of different types of product information on consumers' choice when purchasing milk or soybean beverages, or about the degree on consumption. Behrens *et al.*[28] studied the effect of nutrition and health claims on the acceptability of four types of yoghurt-like fermented soyamilk and concluded that information positively influenced acceptance, although such influence was limited by the subjects' sensory experience. More recently, Jones *et al.*,[29] carried out a cross-cultural study (New Zeeland and USA) about consumer perception of soy and dairy products in order to collect consumer views and opinions about the associated health benefits and product claims. They concluded that there were minimal differences between USA and NZ consumers with respect to their knowledge of health and product benefits of soy and dairy products. However, NZ consumers had a greater preference for dairy products. There is no information available about how certain consumer attitudes, like an interest in healthy eating or towards new foods, can influence the acceptability of soy and dairy products.

The objectives of this work were: 1) To study how information type (product image or beverage type and nutritional facts) and consumer attitudes and beliefs affected the hedonic ratings and purchase intention of milk and soybean vanilla beverages; 2) To analyse to what extent the expectations created by information affected the hedonic ratings of these products.

2. MATERIAL AND METHODS

2.1. Subjects

Subjects were recruited by a local consumer association (Asociación Valenciana de Consumidores y Usuarios, AVACU) through a short questionnaire sent by mail. The participants were selected according to the following criteria: age, gender and habitual consumers of milk and/or vegetable beverages. Prior to the test, it was confirmed that participants had no allergies to milk or soy. Of the original one-hundred-and-twenty participants selected (74 women and 46 men), twelve were unavailable to complete the experimental sessions. Hence, their data were not used in the analyses.

2.2. Samples

Six commercial samples were selected, of which three were vanilla-milk beverages and the other three vanilla-soymilk beverages, of different brands and characteristics (Table 1). The selection criteria were based on prior analysis of product range and identification of leading market brands. The samples were purchased from the local market, taking into account expiry dates (the same for each brand) and were stored at 4 ± 1ºC prior to testing. All measurements were performed within the declared shelf-life period of each sample.

Table 1. Ingredients and main characteristics of commercial milk and soymilk vanilla beverages samples.

Sample[a]	Main ingredients[b]	Hydrocolloid[b]	Dietary fibre[b] (g Kg^{-1})	Soluble solids (ºBrix)[c]	pH[c]
M1	Skimmed milk	Carrageenan Guar-gum	-	17.0 (0.07)	6.68 (0.06)
M2	Skimmed milk Dairy solids	-	-	14.7 (0.11)	6.82 (0.13)
M3	Semi-skimmed milk Dairy solids	Carrageenan	-	18.4 (0.11)	6.82 (0.02)
S1	Soybean	-	12	15.8 (0.04)	6.76 (0.13)
S2	Soybean	-	6	18.3 (0.04)	7.64 (0.03)
S3	Soybean	-	20	10.5 (0.06)	6.99 (0.05)

[a]Identification of sample commercial brands. Milk beverages: Central Lechera Asturiana (M1), Choleck (M2) and Okey (M3). Soymilk beverages: Bjorg (S1), Fit&Activ (S2) and Sojalia (S3).
[b]Declared on label.
[c]Average value of two samples, with standard deviations within parentheses.

2.3. Sensory analysis procedure

The study was carried out in two sessions, one month apart, in a standardized test room[30] in morning (11:00-13:00) or afternoon groups (15:30-17:00). At the beginning, participants were given instructions stating that they were to participate in hedonic and purchase intention evaluations for six types of milk and soymilk commercial beverages.

In the first session, only the six samples without information were presented (blind condition, B) in order to evaluate the overall acceptability and purchase intention of the 108 participants. Overall acceptability of the samples was tested using a 9-point hedonic scale ranging from 1 (“dislike extremely") to 9 ("like extremely") and purchase intention using a 5-point scale from 1 ("definitively would not buy") to 5 ("definitively would buy").

In the second session, first of all participants were provided with information about the products. Two information types were used: picture of real package or card with beverage type and nutritional facts. The pictures showed the commercial brands of the products. The cards contained information selected from the commercial packages about the beverage type (milk or soymilk), and about nutritional facts of the product (compositional details, energetic value and fat content). Participants were divided into two subgroups, depending on the kind of information they received, pictures (n = 55) or cards (n = 53). The subjects were asked to look at the picture or card and to rate how acceptable they expected the product to be and their purchase intention (expected condition, E). Next, the subjects completed a questionnaire designed to measure their interest in eating healthily with the multiple scale labelled as "General health interest", proposed by Roininen *et al.*,[31] and their attitudes towards new food with the multiple scale of "Food Neophobia" developed by Pliner and Hobden.[32] The Spanish version of the both scales (Tables 2 and 3) were based on the initial proposal by Barrios (unpublished data), slightly modified. Each multiscale was composed of a group of statements (8 and 10, respectively) and the corresponding Likert's five-point agreement subscales,with the categories ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The statements were positive or negative, the latter were recoded for the final scores. Finally, the subjects were given the picture or the card (depending on the subgroup to which they belonged) and the corresponding product to be tasted at the same time (informed condition, I). The rating procedures were similar to those in earlier phases.

Table 2. General health interest multiple scale: original version and corresponding Spanish translation[a]

	English version [b]	Spanish version
1.R	The healthiness of food has a little impact on my food choices.	Cuando elijo un alimento me importa poco que sea o no saludable.
2.	I am very particular about the healthiness of food I eat.	Considero importante que los alimentos que consumo sean saludables.
3.R	I eat what I like and I do not worry much about the healthiness of food.	Como lo que me gusta sin preocuparme si es o no es saludable.
4.	It is important for me that my diet is low in fat.	Para mí es importante que mi dieta sea baja en grasa.
5.	I always follow a healthy and balanced diet.	Siempre sigo una dieta equilibrada y saludable.
6.	It is important for me that my daily diet contains a lot of vitamins and minerals.	Para mí es importante que mi dieta sea rica en vitaminas y minerales.
7.R	The healthiness of snacks makes no difference to me.	Cuando tomo algo de aperitivo o entre comidas, no me preocupa que sea o no saludable.
8.R	I do not avoid foods, even if they may raise my cholesterol.	No me privo de tomar algunos alimentos aunque su consumo pueda elevar mi colesterol.

[a]Negative statements are marked with an “R” after the statement number. These statements were recoded for the final scores.
[b]Roininen *et al*.[31]

Table 3. Food neophobia multiple scale: original version and corresponding Spanish translation [a]

	Original version [b]	Spanish version
1.R	I am constantly sampling new and different foods.	Siempre tiendo a elegir alimentos nuevos o diferentes.
2.	I don't trust new foods.	No confío en los alimentos nuevos.
3.	If I don't know what is in a food, I won't try it.	Si no sé que es lo que contiene un alimento, no lo pruebo.
4.R	I like foods from different countries.	Me gustan los alimentos de distintos países.
5.	Ethnic food looks too weird to eat.	Me resulta demasiado extraña la comida típica de otros países para comerla.
6.R	At dinner parties, I will try a new food.	En las fiestas y celebraciones estaría dispuesto a probar algún nuevo alimento.
7.	I am afraid to eat things I have never had before.	No me atrevo a comer cosas que no he probado antes.
8.	I am very particular about the foods I will eat.	Soy muy escrupuloso con los alimentos que tengo que comer.
9.R	I will eat almost anything.	Me comería casi cualquier cosa.
10.R	I like to try new ethnic restaurants.	Me gusta probar nuevos restaurantes típicos de distintos países.

[a]Negative statements are marked with an "R" after the statement number. These statements were recoded for the final scores.
[b]Pliner and Hobden.[32]

The samples or the information type (picture or card) were coded with three-digit random numbers. Samples (30 mL) were served at 10 ± 1ºC in white plastic cups and mineral water was provided for mouth-rinsing. To avoid first position distortions and possible carry-over effects, the presentation order followed a Williams design for six samples[33] within each of the three conditions and they were presented monadically. Data acquisition was performed using Compusense® *five* release 4.6 software (Compusense Inc., Guelph, Ontario, Canada).

2.4. Data analysis

Two-way analyses of variance (ANOVA) with interactions, sample and information type as sources of variation, were carried out on acceptability and on purchase intention data obtained in both expected and informed conditions. Two-way ANOVA, without interaction, was performed on acceptability data within each phase with sample and consumer being sources of variation. These analyses were carried out for each of the subgroups of consumers with different information types. Significance of differences between samples was determined by the Fisher test ($\alpha \leq 0.05$). Student's *t*-tests ($P \leq 0.05$) were carried out to detect differences between expected and blind (E-B), informed and blind (I-B) and informed and expected (I-E) conditions. The relationship between E-B and I-B values were determined by linear regression. Analyses were performed by XLSTAT-Pro software v. 2007 (Addinsoft, France).

The internal consistency of the Spanish multiscales was measured with the Cronbach's alpha coefficient[34] with the equation:

$$\alpha = \frac{k\bar{r}}{1+\bar{r}(k-1)}$$

where k is the number of statements in each multiscale, and $\bar{r}$ is the average interstatement correlation. The individual score for each attitudinal multiscale was calculated by adding the score obtained for each statement. For "General health interest" scale[31] theoretical score ranged from 8 to 40 and for "Food Neophobia" scale[32] theoretical score ranged from 10 to 50.

3. RESULTS AND DISCUSSION

3.1. Effect of the type of information on acceptability and purchase intention

First of all, the extent to which information type affected acceptability and purchase intention were analysed in two situations: when the consumer received product information alone or when they received the information together with the product. When they received product information alone, a significant effect of the interaction between samples and type of information ($P \leq 0.001$, Table 4) was detected for both acceptability and purchase intention of samples. The significance of this interaction indicated that the influence of the information type was not the same for all the samples. For four of them (M1, M2, S2, S3) information type did not influence either expected acceptance or purchase intention and both were significantly higher in the milk samples (Fig. 1). In the other two samples (M3, S1) significant differences were detected. Expected acceptability of milk sample M3 was higher when the information card was provided than when the product picture was given (Fig. 1a).

Table 4. Two way analyses of variance (n = 108) with interactions for acceptability and purchase intention data on expected and informed conditions

Study stage	Source	Acceptability		Purchase intention	
		F-ratio	*P*-value	*F*-ratio	*P*-value
Expected condition	Type of information	0.071	0.790	0.040	0.842
	Sample	14.023	< 0.0001	20.819	< 0.0001
	Type of information*sample	7.475	< 0.0001	4.012	0.001
Informed condition	Type of information	4.409	0.036	1.705	0.192
	Sample	82.732	< 0.0001	65.355	< 0.0001
	Type of information*sample	0.842	0.520	0.308	0.908

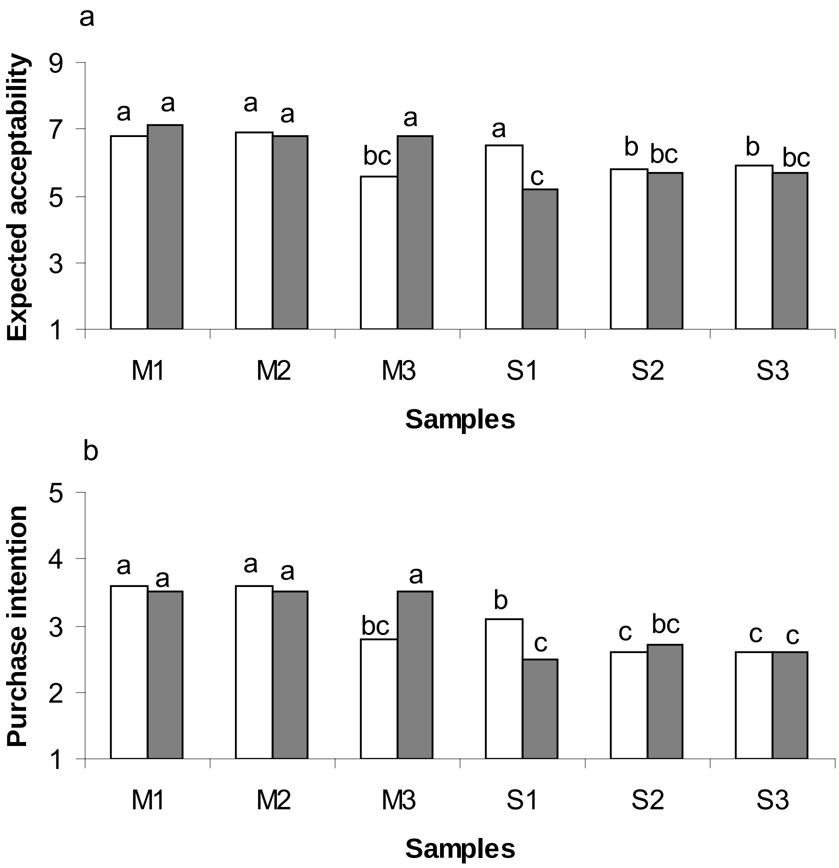

Figure 1. Effect of the type of information, picture ( ) or information card ( ), on a) acceptability and b) purchase intention of the samples in the expected condition. Different letters on top of bars indicate significant differences (α = 0.05). Identification of samples in Table 1.

By contrast, for sample S1, expected acceptability was higher for consumers provided with the picture than those given the product information card. Among the milk samples, the package of sample M3 was the least attractive and could have made the consumers think that its low quality design was an indication that in contained a poor quality product. The contrary was observed for sample S1, for which the product image transmitted by the photograph made the consumers think that the package contained a good quality product and increased its purchase intention (Fig. 1b). This coincides with that observed by other authors with respect to how the image or the package influence consumer response. The suggestibility of packages and labels is increasingly being shown to exert an influence on consumer's trial of a food.[35] Deliza *et al.*[36] found that the amount of information and background colour, followed by brand and language were the features that predominantly affected expected liking for passion-fruit juice.

When the assessment was carried out with information available on testing the sample, a significant effect on the acceptability was detected for the interaction between information type and samples (P = 0.036, Table 4). The samples were considered more acceptable when the consumers tried them accompanied by an image of them (average = 5.8) than when they were given the cards containing the nutritional information (average = 5.5).

3.2. Influence of consumer attitudes and beliefs on acceptability and purchase intention

The internal consistency of the Spanish version of the "General health interest" and "Food Neophobia" multi-item scales was calculated by the Cronbach's alpha coefficient. The values obtained, α = 0.79 and α = 0.82, respectively, were similar to those obtained by other authors for other versions of these scales. For example, for the Dutch version of the "General health interest" scale, Roininen *et al.*[31] obtained a value of α = 0.80 and Zandstra *et al.*[37] of α = 0.77. For the Finnish version of the "Food Neophobia" scale, Tuorila *et al.*[38] obtained a value of α = 0.85.

Population distribution in terms of their interest in eating healthily and attitudes to new foods (Figs. 2a and 2b, respectively) indicated that the majority of people in the population showed quite a lot of interest in eating healthily and that there were very few cases of consumers who displayed a certain degree of neophobia.

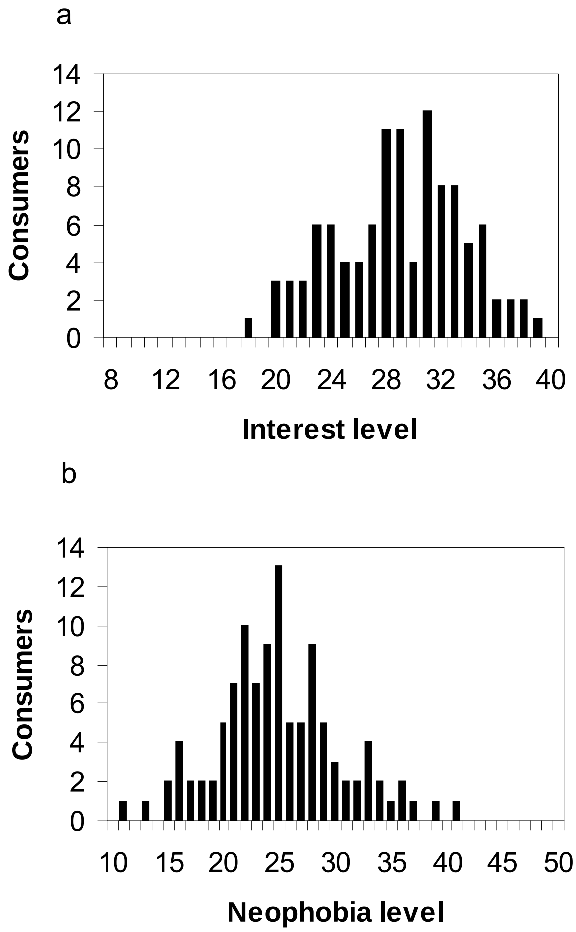

Figure 2. Consumers distribution related to a) eating healthily interest and b) food neophobia.

In accord with this situation, respondents were divided into three groups depending on their scale values, using the 33rd and 66th percentile points as cut-off points. These groups were designated low, moderate and high groups, respectively. The moderate group was removed in order to study the effect the information had on the subgroups with more clearly defined attitudes. The actual range for the “General health interest” scale was 18-39, the respondents with lowest interest had scores 18-27 and with highest interest, 32-39. For the “Food neophobia” scale the actual range was 11-41; respondents with lowest neophobia had scores of 11-22 while the highest neophobia scores were 28-41. The differences in the degree of neophobia demonstrated by the consumers did not influence either acceptability or purchase intention, both in the expected and the informed condition ($P \geq 0.5$).

Differences in the degree of interest in eating healthily influenced both the differences in acceptability and purchase intention for the different samples, in the results obtained for the expected condition as well as for the informed condition ($P < 0.01$). The expected acceptability and purchase intention of S2 and S3 soymilk samples were significantly higher for consumers with interest in eating healthily than for the other consumers (Tables 5 and 6).

Table 5. Influence of "General health interest" on acceptability of milk and soymilk vanilla beverages[a,b]

Sample[c]	Expected condition		Informed condition	
	Lower interest	Higher interest	Lower interest	Higher interest
M1	7.0a	6.8ab	7.2ab	7.1ab
M2	7.1a	6.7abc	7.5a	7.0ab
M3	6.1bcd	6.0cd	7.3ab	6.6b
S1	5.9de	6.4abcd	3.4f	4.8cd
S2	5.2e	6.4abcd	4.8cd	5.4c
S3	5.2e	6.2bcd	3.6ef	4.3de

[a]For each condition (expected and informed) values within a column and/or a row with different letters from each one of the ANOVAs are significantly different (α = 0.05).
[b]Values from 1 "dislike extremely" to 9 "like extremely".
[c]Identification of samples in Table 1.

However, when both information and sample were provided (informed condition), only S1 was considered significantly more acceptable by consumers with higher interest in eating healthily. Moreover, the aforementioned group of consumers declared a significantly higher purchase intention for all soymilk samples. These results are in accordance with the observations reported by Aaron *et al.*[39] concerning the relationship between consumer attitudes and beliefs and their response to food. When consumers tasted the samples, the effects of information were more important on purchase intention than on hedonic ratings. Tuorila *et al.*[40] found that nutritional information had an effect on purchase interest, but less impact on the perceived pleasantness of a snack food. Hedonic responses to foods may shift, but the process is slow as repeated exposure is usually necessary.[41]

Table 6. Influence of "General health interest" on purchase intention of milk and soymilk vanilla beverages[a,b]

Sample[c]	Expected condition		Informed condition	
	Lower interest	Higher interest	Lower interest	Higher interest
M1	3.7a	3.5ab	3.9ab	3.9ab
M2	3.8a	3.5ab	4.1a	3.7ab
M3	3.3bc	3.0cd	3.8ab	3.4bc
S1	2.8de	3.1bcd	1.6g	2.5de
S2	2.4e	3.0cd	2.6ef	2.9cd
S3	2.4e	3.0cd	1.8fg	2.3e

[a]For each condition (expected and informed) values within a column and/or a row with different letters from each one of the ANOVAs are significantly different (α= 0.05).
[b]Values from 1 "definitively would not buy" to 5 "definitively would buy".
[c]Identification of samples in Table 1.

3.3. Expectations created by information and their effects on acceptability

A study was made of the extent to which sample acceptability was influenced by the expectations generated by the two information types. To do this, mean scores for each sample were compared in the blind condition (B), in the expected condition (E) and in the informed condition (I). Expected minus blind scores (E-B) were calculated and a paired *t*-test was carried out to test significant differences between the mean ratings of the two conditions for each sample. A significant effect revealed that a disconfirmation occurred. Informed minus blind scores (I-B) were also calculated for each sample, significant differences revealing a significant effect of information on informed liking scores. A contrast was revealed when (I-B)/(E-B) < 0 and an assimilation effect when (I-B)/(E-B) > 0. When assimilation was detected informed minus expected scores (I-E) were calculated. Significant differences meant that the score when tasting with information available was located between the blind score and the expected score. Thus assimilation was not complete and both sensory hedonic dimension and expectation had an impact on the informed scores.[17,42]

When the picture information subgroup rated acceptance with the information available (I), mean ratings of milk beverages were higher than in the two previous phases (B and E), while soymilk beverages mean ratings were intermediate between blind and expectation ratings. A negative disconfirmation (product worse than expected) occurred in the evaluations of all soymilk beverages and of the milk sample M2, while a positive disconfirmation (product better than expected) occurred for sample M3 (Table 7).

Table 7. Overall acceptability mean values (*n* = 55)[a] of vanilla beverages evaluated under blind, expected and informed conditions by consumers with image of the product. Differences between the mean ratings tested through paired *t*-test

Products	Blind	Expected	Informed	E-B		I-B		I-E	
				M	*P*	M	*P*	M	*P*
M1	6.7a	6.8a	7.2a	0.1	0.683	0.5	0.107		
				N.S.		N.S.			
M2	6.0b	6.9a	7.1a	0.9	0.003	1.1	0.001	0.2	0.407
				Disconfirmation -		Assimilation			
M3	6.6a	5.6b	7.2a	-1.0	0.001	0.6	0.079		
				Disconfirmation+		N.S.			
S1	3.2d	6.5a	4.0c	3.3	<0.0001	0.8	0.028	-2.5	<0.0001
				Disconfirmation -		Assimilation			
S2	4.2c	5.8b	5.3b	1.6	<0.0001	1.1	0.006	-0.5	0.155
				Disconfirmation -		Assimilation			
S3	3.5d	5.9b	4.1c	2.4	<0.0001	0.6	0.085		
				Disconfirmation -		N.S.			

[a]From ANOVA, means in the same column with different letters are significantly different (α = 0.05).

Significant differences were found in informed minus blind scores for samples M2, S1 and S2, which revealed that the information affected their respective informed acceptability scores. The quotient (I-B)/(E-B) > 0 indicated that the aforementioned effect could be explained by the assimilation model. The significant difference between the informed minus the expected score for sample S1 revealed that consumers did not completely assimilate towards their expectation (the expectancy was significantly higher than the informed acceptability). Moreover, that fact that this difference was negative would indicate that information played a secondary role when compared to sensorial quality. If consumers do not completely assimilate towards expectations it can be assumed that they will revise their expectations in following exposures as observed by Lange *et al.*[17] Assimilation was completed for samples M2 and S2, thus the information provided caused the final evaluation of samples to be close to the expected score.

For the subgroup of consumers with information cards, expected ratings were higher than the blind liking mean for all samples and significant differences were found between milk and soymilk samples (Table 8). Generalizing, when acceptance was rated with having information available, mean ratings were closer to expectation ratings than to blind condition ratings. Negative disconfirmation was found for all samples, with the exception of sample M3. Besides, information had a significant effect on informed liking ratings, generating an assimilation effect for samples M1, M2, S1 and S2, but only for milk beverages was this effect complete. Sensory quality of S1 and S2 beverages seemed more decisive than information provided and so the assimilation effect was incomplete for these samples.

Table 8. Overall acceptability mean values (*n* = 53)[a] of vanilla beverages evaluated under blind, expected and informed conditions by consumers with information card of the product. Differences between the mean ratings tested through paired *t*-test

Products	Blind	Expected	Informed	E-B		I-B		I-E	
				M	*P*	M	*P*	M	*P*
M1	6.3a	7.0a	7.1a	0.7	0.012	0.8	0.009	0.1	0.946
				Disconfirmation -		Assimilation			
M2	6.0a	6.8a	7.1a	0.8	0.012	1.1	0.002	0.3	0.327
				Disconfirmation -		Assimilation			
M3	6.4a	6.8a	6.6a	0.4	0.201	0.2	0.404		
				N.S.		N.S.			
S1	2.8c	5.2c	4.1c	2.4	<0.0001	1.3	0.004	-1.2	0.005
				Disconfirmation -		Assimilation			
S2	3.9b	5.8b	4.8b	1.9	<0.0001	0.9	0.040	-1.0	0.018
				Disconfirmation -		Assimilation			
S3	3.1c	5.7b	3.5c	2.6	<0.0001	0.4	0.456		
				Disconfirmation -		N.S.			

[a]From ANOVA, means in the same column with different letters are significantly different ($\alpha \leq 0.05$).

As stated to be typical in food studies,[16] the main effect exerted by both information types could be explained by the assimilation model (when the liking for a product moves in the direction of expectations, Tables 7 and 8). There are previous studies which report assimilation effects in the presence of both positive and negative disconfirmations.[6,17,43-45]

The regression slopes of the function representing (I-B) vs. (E-B) for each product were positive, which reinforces that information caused assimilation as the main effect. However, the values of the fit (R^2) to the lineal model oscillated between 0.1 and 0.6, indicating that the information gave rise to another type of behavior. For instance, Fig. 3 represents the fits obtained for one of the milk samples (M2) and for one of the soy-milk samples (S1), for both information types (picture and card).

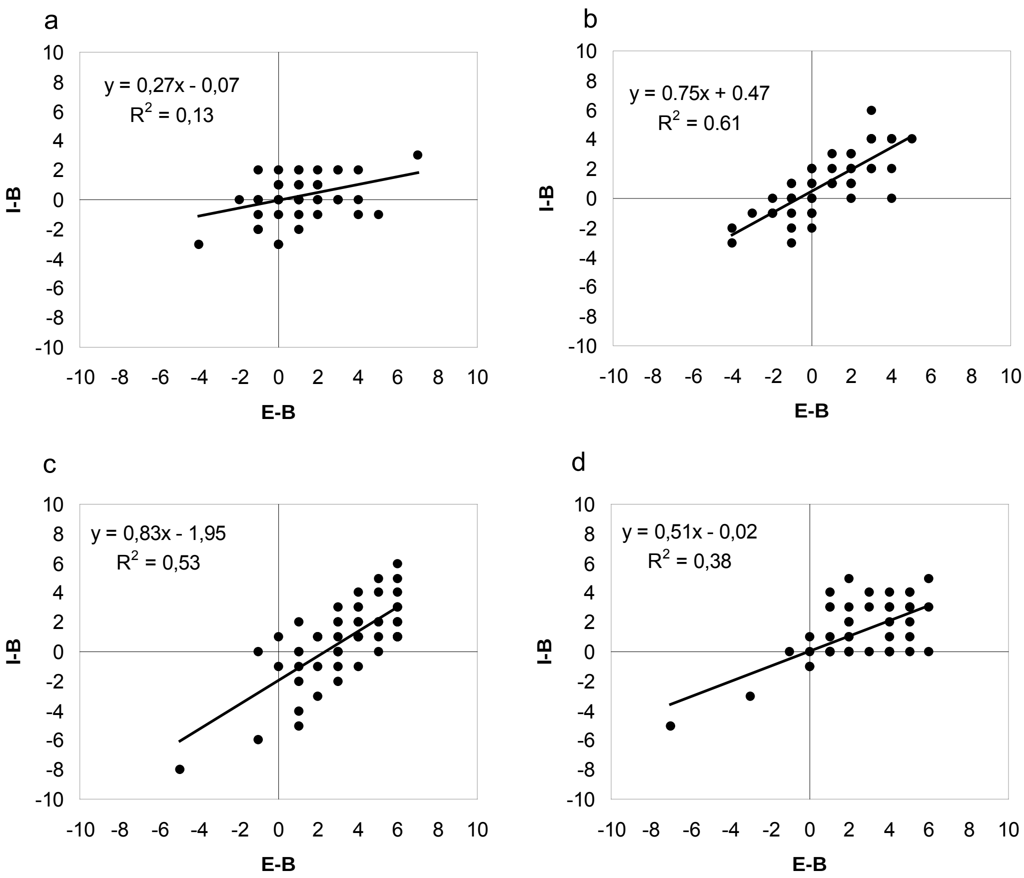

Figure 3. Linear regression plot of (I-B) vs. (E-B) for sample M2, a) with picture and b) with informed card and S1, c) with picture and d) with informed card. Equation and proportion of variance explained.

When individual consumer information was studied, contrast phenomena were observed, types of behavior without tendencies and, to a lesser extent, the absence of any effect of the information (Table 9). For any sample and information type, except for sample M3 when it was presented together with its image, the percentage of assimilation cases after the negative disconfirmation (E > B) was much greater than after the positive disconfirmation (E < B). This tendency agreed with that observed by Siret and Issanchou[42] and by Caporale and Monteleone[46] rather than with Schifferstein *et al.*[43] The contrast effect (when a liking for the product moves in the opposite direction to the expectations) was observed in a lower percentage of individuals (up to 25.4%) and was more noticeable for the subgroup that received the pictures. Finally, for all the samples there was a considerable percentage of individuals (16.4 – 58.1%) whose behaviour did not fit in with any of these models.

Table 9. Proportion of consumers showing assimilation, contrast, unclear or no effect of expectation created by information

Effects	Subjects % Picture (*n* = 55)	Card (*n* = 53)
M1		
Assimilation under:		
Negative disconfirmation (E > B)	23.6	39.6
Positive disconfirmation (E < B)	14.5	9.4
Contrast	3.6	5.7
No effect (B = E = I)	9.1	13.2
Unclear	49.0	32.1
M2		
Assimilation under:		
Negative disconfirmation (E > B)	47.3	49.1
Positive disconfirmation (E < B)	9.1	15.0
Contrast	7.3	3.8
No effect (B = E = I)	7.3	3.8
Unclear	29.0	28.3
M3		
Assimilation under:		
Negative disconfirmation (E > B)	16.4	32.1
Positive disconfirmation (E < B)	14.5	15.1
Contrast	25.4	9.4
No effect (B = E = I)	7.3	7.6
Unclear	36.4	35.8
S1		
Assimilation under:		
Negative disconfirmation (E > B)	63.6	52.8
Positive disconfirmation (E < B)	3.6	3.8
Contrast	16.4	0
No effect (B = E = I)	0	1.9
Unclear	16.4	41.5
S2		
Assimilation under:		
Negative disconfirmation (E > B)	60	54.7
Positive disconfirmation (E < B)	5.5	7.5
Contrast	16.4	9.4
No effect (B = E = I)	3.6	5.7
Unclear	14.5	22.7
S3		
Assimilation under:		
Negative disconfirmation (E > B)	49.1	50.9
Positive disconfirmation (E < B)	7.3	3.8
Contrast	18.2	9.4
No effect (B = E = I)	1.8	5.7
Unclear	23.6	30.2

4. CONCLUSIONS

The results obtained confirm that, on one hand, the characteristics of the package can influence the consumers' opinion about the possible acceptability of the product and on their purchase intention. A badly designed or unattractive package can make the consumer think that the product has low acceptability and reduces their interest in acquiring it. By contrast, a well-designed package suggests that the product it contains is high quality and increases the consumer's interest in acquiring it. When the consumer, as well as seeing the package tastes the product, the package may not influence either acceptance or purchase intention. On the other hand, it has been demonstrated that an interest in eating healthily can increase purchase intention and even raise acceptability of the different types of products with specific nutritional characteristics, like soy-milk beverages.

In general, consumers' response to the expectations generated by the two information types (picture of real package or card with beverage type and nutritional facts) followed an assimilation model. However, an analysis of the individual responses indicated different tendencies in the responses in terms of the information type. The percentage of consumers whose response fit the assimilation model was higher for the samples of soy-milk beverages (55-67%) than for the dairy beverages (31-64%), independent of the information type supplied. In the dairy beverages, this percentage was higher when the information was supplied on a card, while for the soy-milk this occurred when the picture of real package was supplied. Globally, the percentage of consumers that were not influenced by the information or whose response did not follow a clear model was greater for the dairy beverages (32-57%) than for the soy-milk ones (16-36%). This leads us to the conclusion that the influence of the expectations generated by the information in the acceptance of a product, not only depends on the information type the consumer receives, but also on the nutritional or sensorial characteristics of each product.

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CAPÍTULO 4

FLOW BEHAVIOUR OF INULIN-MILK BEVERAGES. INFLUENCE OF INULIN AVERAGE CHAIN LENGTH AND OF MILK FAT CONTENT

Beatriz Villegas and Elvira Costell

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ABSTRACT

The effects of the addition of different types of inulin (oligofructose, native and long chain) at different concentrations (2%, 4%, 6%, 8% and 10%, w/w) on the flow behaviour of milk beverages model systems were studied. The flow of the inulin-milk solutions was Newtonian, except for whole milk samples with higher long chain inulin concentrations (8 and 10%) which were shear-thinning. The flow of all inulin-κ-carrageenan-milk samples, were shear thinning. The viscosity of 3.1% fat whole milk could be approximated by skim milk with 4-10% short chain inulin, or with 6-8% native inulin or with 4-6% long chain inulin. In κ-carrageenan-milk samples the addition of inulin could not replace the effect of milk fat on the viscosity of these systems.

Keywords: milk beverages; Flow behaviour; Inulin; κ-carrageenan; Milk fat content

1. INTRODUCTION

Inulin is a natural component of several fruits and vegetables. It is mainly obtained from chicory roots by an extraction process with hot water, followed by purification and crystallisation. Native inulin is a mixture of oligomers and longer polymer chains with a variable number of fructose molecules, usually including a glucose molecule at the end of the chain. The degree of polymerisation of the chains ranges between 2 and 60 units and is commonly characterised by the average degree of polymerisation, which in native inulin is approximately 12. By partial enzymatic hydrolysis of the native inulin with endo-inulinase, oligofructose, with a polymerisation degree between 2 and 7, with an average value of 4, can be obtained. Alternatively, the oligomers with a polymerisation degree below 10 can be separated from native inulin by physical methods (ultrafiltration, crystallisation, etc), and a long-chain inulin with an average degree of polymerisation between 22 and 25 is thus obtained (Franck, 2002; Moerman, Van Leeuwen & Delcour, 2004).

In addition to its beneficial effects on health, as a dietetic fibre and as a prebiotic ingredient (Flamm, Glinsmann, Kritchevsky, Prosky, & Roberfroid, 2001; Roberfroid & Slavin, 2000), inulin shows interesting technological properties, as a low-calorie sweetener, as a fat substitute, or it can be used to modify texture (Tungland & Meyer, 2002). These properties are linked to the degree of chain polymerisation. The short-chain fraction, oligofructose, is much more soluble and sweeter than native inulin, with a sweetness profile similar to that of sucrose, lower sweetening power (30-35%) and a low caloric content (1-2 $kcalg^{-1}$). Long-chain inulin is more thermally stable, less soluble and more viscous than the native product (Wada, Sugatani, Terada, Ohguchi & Miwa, 2005), and can be used as a fat substitute, with an efficiency that is practically double than that of native inulin (Coussement, 1999; Voragen, 1998). Its properties as a fat substitute are attributed to its capacity to form microcrystals that interact with each other forming small aggregates, which occlude a great amount of water, creating a fine and creamy texture that provides a mouth sensation similar to that of fat (Bot, Erle, Vreeker & Agterof, 2004; Franck, 2002; Kaur & Gupta, 2002).

The combined consideration of its nutritional and technological characteristics makes inulin a very attractive ingredient. In most cases, its addition to different foods has been done in order to increase fibre ingestion, in amounts that ranges from 3 to 6g per portion, or to assure its bifidogenic nature, by adding 3-8g per portion (Coussement, 1999). Despite the great number of commercial products including it in their formulation, there is still little information available referring to its physical properties and to the effects produced by its incorporation on the physical characteristics of different types of foods. Some authors have analysed the effect of adding inulin on the rheological and sensorial characteristics of several dairy products, like ice-creams (El-Nagar, Glowers, Tudorica & Kuri, 2002; Schaller-Povolny & Smith, 1999, 2001) yoghurts (Dello Stafollo, Bertola, Martino & Bevilacqua, 2004; El-Nagar et al., 2002; Guven, Yasar, Karaca & Hayaloglu, 2005), fresh cheese (Koca & Metin, 2004; Hennelly, Dunne, O'Sullivan & O'Riordan, 2006) and dairy desserts (Tárrega & Costell, 2006). In most of these works the objective was to use inulin, generally one with a high degree of polymerisation, in low-fat food formulations. There is little information on the rheological behaviour of inulin and the effect on the same of the possible interactions with other ingredients, like different types of hydrocolloids or starch (Bishay, 1998; Giannouli, Richardson & Morris, 2004; Zimeri & Kokini, 2003a). Likewise, some information exists on the differences in the physico-chemical properties of oligofructose and inulins with different degrees of polymerisation (Blecker et al., 2003; de Gennaro, Birch, Parke, & Stancher, 2000; Schaller-Povolny, Smith & Labuza, 2000). The latter studies have been carried out in aqueous systems and no data has been found regarding the physical properties of inulin in other media like, for example, dairy systems.

The aims of this work were: (1) to study the effect of the addition of different types of inulin (oligofructose, native and of long chain) on the flow behaviour of milk beverages model systems with or without milk fat and/or κ-carrageenan and (2) to compare the viscosity of the whole milk samples with that of skimmed milk samples with different concentrations of the three types of inulin added.

2. MATERIALS AND METHODS

2.1. Materials and samples preparation

Three types of inulin: long chain length (≥ 23 monomers) (Frutafit TEX!), native (9-12 monomers) (Frutafit IQ) and with a high level of short chain molecules or oligofructose (2-10 monomers) (Frutafit CLR) from Sensus (Brenntag Química, Spain), κ-carrageenan (Satiagel ABN 26, SKW Biosystems, France) and skimmed and whole milk powders (Central Lechera Asturiana, Spain) were used.

Two lots of 32 samples each were prepared: without and with κ-carrageenan (0.02%, w/w). Each lot was divided into two sublots: one with whole milk (3.12% fat content) and another one with skimmed milk (0.1% fat content). For each sublot, a sample without inulin added and samples with different concentrations (2%, 4%, 6%, 8% and 10%, w/w) of each of the three types of inulin were prepared. Two preparations for each composition were done.

Inulin-milk beverages were prepared by dispersing 12% (w/w) milk powder and the corresponding inulin concentration in deionised water, at 250rpm and 70ºC for 15 min, with the help of a magnetic stirrer and a hot plate (Ared, Velp Scientifica). Samples were stored in refrigeration (4±1ºC) during 24h before measurement.

Kappa-carrageenan was dissolved in deionised water at room temperature for 5 minutes and then at 70ºC for 10 minutes, agitating with a magnetic stirrer at 250rpm. These solutions were kept refrigerated (4±1ºC) for 24 hours before mixing with inulin-milk dispersions. Mixing was performed at 250rpm and 70ºC for 5 min. Samples were then kept at 4±1ºC for 4h before measurement.

2.2. Flow measurement

Flow measurements were carried out in a concentric cylinders viscometer Haake model VT 550, using a double gap sensor NV (radii ratio=1.02, length=60mm) and controlled by the Rheowin Pro software (version 2.93, Haake). Shear stress was registered at shear rates from 1 to 600s^{-1} with a ramp of 120s. For each sample, measurements were done in triplicate at a controlled temperature of 5±1ºC using a Phoenix P1 Circulator device (Thermo Haake). A fresh sample was loaded for each measurement.

Experimental data were fitted to the Newton model

$$\sigma = \eta\dot{\gamma} \qquad (1)$$

or to the Ostwald-de Waele model

$$\sigma = K\dot{\gamma}^{n} \qquad (2)$$

using the Rheowin Pro software (version 2.93, Haake). Where η (mPas) is the Newtonian viscosity, K (mPas^n) is the consistency index and n is the flow index. For samples showing Newtonian flow, viscosity values were used for the characterisation and comparison of samples. For samples with shear thinning flow, since parameter K units depend on n values, apparent viscosity values at 1s^{-1} (η_1) were used to compare samples viscosity.

2.3. Experimental design and data analysis

For each of the four sublots of samples, the influence of the inulin type and of the inulin concentration and their interactions on the flow parameters values were studied using a factorial design with two factors: inulin type (3 levels) and inulin concentration (6 levels). Analyses of variance of two factors with interactions were applied to the different sets of data. Least significant differences (LSD) were calculated by the Fisher´s test ($\alpha \leq 0.05$). These analyses were performed with the Statgraphics Plus 4.1 software.

3. RESULTS

3.1. Flow behaviour of inulin-milk beverages

Inulin-milk solutions for both skimmed and whole milk, showed a homogeneous appearance after the preparation process. After cooling and storage in refrigeration during 24h, no visual changes in the samples were observed, except for samples with 8% and 10% (w/w) long-chain inulin. In these samples a slight sedimentation, that clearly increased after refrigeration storage during 48 and 72h, was observed. According to Kaur and Gupta (2002), the long-chain inulin is less soluble than oligofructose and has the ability to form inulin microcrystals when sheared in water or milk. Zimeri and Kokini. (2003b), using light microscopy, observed the presence of some inulin crystals immersed in the continuous phase in water solutions of 5% (w/w) long chain inulin. They postulated that these crystals could have been the result of either insolubility or recrystallisation after hot inulin dispersions were cooled. Due to the influence of temperature on solubility of inulin (Kim, Faqih & Wang, 2001), it is probable that the sedimentation observed in the above mentioned samples be due to a recrystallisation mechanism. The latter authors hypothesised that when inulin solutions were heated at moderate temperatures (60-70ºC), the polymer chains may have more active movement in the solution due to higher kinetic energy. Thus the better contact between inulin chains becomes easier during cooling to form aggregates of small inulin crystals. The initial inulin concentration and the size of the inulin chains may affect both the crystallisation and the aggregation processes and consequently the rate of sedimentation (Bot et al., 2004). The longer chains have a lower solubility than the shorter ones and therefore they will crystallise more rapidly, what could explain the slight sedimentation observed in the samples with 8% and 10% (w/w) long chain inulin.

Before flow measurement, samples that showed inulin sedimentation were manually stirred to favour homogenisation. The variation of shear stress (σ) values with shear rate ($\dot{\gamma}$) for inulin-skimmed milk samples fitted well to Newton model with R^2 values between 0.960 and 0.994. These samples showed flow behaviour typical of dilute solutions with solute concentrations below the critical one, at which entanglement or aggregation between polymer chains begins (Kim et al, 2001; Morris, 1995). This behaviour is similar to that observed by Bishay (1998) and by Zimeri and Kokini (2003a) in inulin aqueous solutions at concentrations lower than 20%. A two-way ANOVA with interaction was used to study the combined effects of the type and concentration of inulin on the variation of viscosity values. The interaction between these factors was significant (F_{int}=173.17, p=0.000), indicating that the effect of inulin concentration on viscosity was different, depending on their average chain length. As expected, for each type of inulin, the same trend was observed: the viscosity values slightly increased with inulin concentration, this increase being higher for samples with long chain length inulin added (Table 1). For samples with lower inulin concentrations (2%, 4%, and 6%) no significant differences in viscosity among the three types of inulin were observed. For the higher inulin concentrations (8% and 10%) samples with long chain inulin added showed the higher viscosity.

Table 1. Viscosity average values (mPas) (*n* = 6) of samples with skimmed milk and with whole milk and different concentrations of short-chain inulin (CLR), native inulin (IQ) and long-chain inulin (TEX!)[a]

Milk type	Inulin type	Viscosity values at different inulin concentrations (%, w/w) 0	2	4	6	8	10
Skimmed (0.1% fat)	CLR		4.83 (0.21)	5.74 (0.08)	5.97 (0.62)	6.39 (0.09)	6.78 (0.19)
	IQ	4.90 (0.34)	5.17 (0.04)	5.41 (0.23)	5.93 (0.01)	6.38 (0.21)	6.88 (0.04)
	TEX!		5.22 (0.03)	5.63 (0.21)	6.21 (0.51)	8.03 (0.45)	13.22 (0.04)
Whole (3.1% fat)	CLR		7.70 (0.07)	7.99 (0.48)	8.74 (0.08)	10.18 (0.01)	10.65 (0.07)
	IQ	6.39 (0.35)	5.20 (0.27)	5.82 (0.20)	6.29 (0.23)	7.11 (0.01)	7.10 (0.30)
	TEX!		5.53 (0.19)	6.41 (0.05)	7.82 (0.71)	18.86[b] (2.02)	70.85[b] (1.84)

[a]Mean values and standard deviations in parentheses.
[b]Samples with shear-thinning flow behaviour; apparent viscosity values at $1s^{-1}$.

For inulin-whole milk samples, the variation of shear stress (σ) values with shear rate ($\dot{\gamma}$) also fitted well to the Newton model ($0.951 \leq R^2 \leq 0.992$), except for samples with higher concentrations (8% and 10%) of long chain inulin. The flow of the latter samples was slightly shear-thinning and fitted well to the Ostwald-de Waele model ($0.986 \leq R^2 \leq 0.992$). A similar change from Newtonian to shear thinning flow, that reflects the transition from dilute to semi-dilute solution behaviour, was observed by Bishay (1998) and by Zimeri and Kokini (2003a) in inulin aqueous solutions at concentrations higher than 20%. As expected, for these samples the consistency coefficient K increased with inulin concentration from 18.86 to 70.85mPas^n while the flow index values decreased from 0.94 to 0.81, indicating an increase in shear thinning behaviour. This change in the type of flow suggests the formation of a weak structure that can be due to an incipient formation of inulin aggregates. These aggregates would contain inulin crystals with significant amounts of fluid phase included within, producing a clear increase of the volume fraction of the dispersed phase (Bot et al., 2004). The aggregates can be relatively strong at low shear rates but they can be easily disrupted by shearing (Bishay, 1998).

Apparent viscosity values at 1s^{-1} were selected to compare samples showing pseudoplastic flow. Two-way ANOVA showed a significant interaction effect between type and concentration of inulin on apparent viscosity values (F_{int} =844.54, p=0.000). For both short chain and native inulins the viscosity values increased slightly with concentration while for long-chain inulin there was a rapid increase in viscosity at concentrations over 6% (Table 1).

3.2. Flow behaviour of inulin- κ-carrageenan-milk systems

No sedimentation was observed visually in inulin-κ-carrageenan-milk samples after cooling and storage in refrigeration during 24h except for 10% (w/w) long chain inulin-κ-carrageenan-skimmed milk samples, in which a very slight sedimentation was observed after storage at 4±1ºC. The lower sedimentation rate of inulin in these samples can be due to the presence of κ-carrageenan. One of the effects of this hydrocolloid in non-gelled dairy products is its ability to inhibit visual phase separation between casein micelles and other polysaccharides (Spagnuolo, Dalgleish, Goff & Morris, 2005; Syrbe, Bauer & Klostermeyer, 1998). At very low concentrations (<0.025%), it prevents sedimentation of cocoa particles in chocolate milk (Vega, Dalgleish & Goff, 2005). In a similar way, the weak structure formed between κ-carrageenan and casein micelles may stabilise the suspension of the inulin crystals by reducing the contact between inulin chains and consequently their rate of aggregation.

Experimental flow data obtained for κ-carrageenan-skimmed milk samples, without and with inulin added, showed shear-thinning flow that fitted well to the Ostwald-de Waele model ($0.986 \leq R^2 \leq 0.996$) with average consistency index (K) values that ranged from 6.13mPas^n for the sample without inulin, to 48.2mPas^n for the sample with 10% long chain inulin concentration. The corresponding average flow index values ranged from 0.99 to 0.85, respectively. In the presence of κ-carrageenan, the effect of the interaction between concentration of inulin and type of inulin on the apparent viscosity values at 1s^{-1} (η_1) (Table 2) and on the flow index (n) values were significant (F=61.47, p=0.000 and F=20.96, p=0.000, respectively). The variation of η_1 values with inulin concentration depended on the inulin type (Table 2). For long chain inulin this variation was similar to that observed for whole milk samples without κ-carrageenan (Table 1).

Table 2. Apparent viscosity average values at $1s^{-1}$ (mPas) (n=6) of samples with κ-carrageenan and with skimmed milk and whole milk and different concentrations of short chain inulin (CLR), native inulin (IQ) and long chain inulin (TEX!)[a]

Milk type	Inulin type	Viscosity values at different inulin concentrations (%, w/w) 0	2	4	6	8	10
Skimmed (0.1% fat)	CLR		15.94 (0.07)	14.34 (0.43)	21.49 (2.25)	15.91 (0.00)	14.88 (4.35)
	IQ	6.13 (0.20)	12.65 (2.08)	11.01 (0.04)	11.58 (0.45)	17.71 (1.15)	14.88 (0.46)
	TEX!		9.36 (0.05)	11.31 (1.25)	14.37 (0.57)	29.91 (2.13)	48.2 (2.49)
Whole (3.1% fat)	CLR		167.65 (22.66)	152.14 (18.34)	135.4 (5.23)	159.82 (37.74)	200.71 (20.45)
	IQ	59.40 (3.99)	65.64 (5.73)	89.99 (4.92)	87.96 (4.13)	79.16 (4.68)	101.99 (0.81)
	TEX!		111.86 (9.81)	117.83 (6.68)	111.93 (13.86)	174.05 (6.11)	174.26 (14.98)

[a] Mean values and standard deviations in parentheses

For κ-carrageenan-whole milk samples, experimental flow data also fitted well to the Ostwald-de Waele model ($0.932 \leq R^2 \leq 0.995$). Also in this group of samples, the effect of the interaction between concentration of inulin and type of inulin on the apparent viscosity values at $1s^{-1}$ (η_1) (Table 2) and on the flow index (n) values were significant (F=5.98, p=0.000 and F=7.00, p=0.000, respectively). Again, a sharp increase in the apparent viscosity values between samples with 6% and 8% long-chain inulin was detected while the viscosity of samples with either short chain length or native inulin added (from 2% to 10%, w/w) did not show a clear variation trend with inulin concentration. In general, the effect of the increase in inulin concentration on the κ-carrageenan-whole milk samples viscosity is less clear than that observed in the inulin-whole milk samples without κ-carrageenan (Table 1).

It seems that the flow behaviour of κ-carrageenan containing samples is governed by the structure formed between the κ-carrageenan molecules and the casein micelles without evidence of a contribution from inulin aggregates. Probably in these systems inulin behaves only as a co-solute with the ability to bind water molecules, thus increasing the solution viscosity. These results are in accordance with the observations made by Giannouli et al. (2004) about the effect of the addition of different inulin concentrations (from 5% to 35%) on calcium pectinate gelation. When they analysed the changes in the storage (G') and loss (G'') moduli for 2.0% low methoxy pectin with different inulin concentrations on cooling from 90 to 5ºC, they found a progressive increase in G' and in G'' values at high temperature (70-90ºC) when increasing inulin concentration but not at 5ºC. They concluded that in these systems the rheological changes observed are swamped by gelation of calcium pectinate or that the presence of the pectin chains inhibits self-association of inulin.

As expected, in the analysed milk beverages, for each lot of samples (Tables 1 and 2) the viscosity values increased with milk fat content.
When an analysis of variance of three factors (type of milk, type of inulin and concentration of inulin) with interactions were applied to the data obtained from each of the two lot of samples (with and without κ-carrageenan), significant effects of the interactions between type of milk and type of inulin were detected. For samples without κ-carrageenan added, the difference in viscosity between inulin-whole milk and inulin-skimmed milk samples was only significant for samples with average long chain inulin added. For samples with κ-carrageenan, significant differences in mean apparent viscosity values between inulin-whole milk and inulin-skimmed milk samples were detected for all of the three types of inulin.

3.3. Inulin as fat replacer in milk beverages

As commented previously, one of the most interesting technological characteristics of inulin and oligofructose is their capacity for acting as a fat replacer in dairy products (Franck, 2002; Guven et al., 2005; Koca & Metin, 2004; Schaller-Povolny & Smith, 1999). By comparing the viscosity of the whole milk samples with the viscosity of skimmed milk samples with different concentrations of the three types of inulin for each lot of samples, clear differences between them can be observed (Table 1). No significant differences in viscosity between whole milk and skimmed milk samples with concentrations from 4% to 10 % short chain inulin were detected. The same results were found for 6% and 8% native inulin or for 4% and 6% long chain inulin. For κ-carrageenan-milk samples, neither of the inulin type or concentrations considered in this work could replace the effect of milk fat on the viscosity of these systems (Table 2).

The results obtained in this work showed that the effect of the inulin average chain length and of the inulin concentration on viscosity of milk beverages depended on the type of milk (skimmed or whole) and on the addition or not of κ-carrageenan.

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CAPÍTULO 5

INULIN MILK BEVERAGES. SENSORY DIFFERENCES IN THICKNESS AND CREAMINESS USING R-INDEX ANALYSIS OF THE RANKING DATA

Beatriz Villegas, Inmaculada Carbonell and Elvira Costell

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ABSTRACT

Inulin has interesting functional properties, which are linked to the average degree of polymerisation of its chains. The aims of this work were to explore the effect of adding different types of inulin (short chain, native and long chain) on the thickness and creaminess of milk-beverage model systems and, to explore the possibility of using each of the three types of inulin as a fat replacer in skimmed-milk beverages. Sensory ranking data were analysed using the R-index. For the two lots of samples (whole milk and skimmed milk), all samples with added inulin were perceived as significantly thicker and creamier than the samples without inulin. The fat mimetic capacity of inulin depended not only on the chain length but also on the concentration of added inulin. In order to obtain milk beverages with reduced fat content having similar thickness and creaminess than those perceived in whole milk beverages, it was necessary to add long-chain inulin at concentrations over 8%.

PRACTICAL APPLICATIONS

In most cases, inulin is added to different foods to supplement them in order to increase fiber ingestion, in amounts that vary between 3 and 6g per portion, or to assure its bifidogenic nature, adding 3-8g per portion. The results of this work provide information regarding the effects of inulin on the sensory characteristics of milk beverages, and show that applying the R-index analysis helped detect the small perceivable differences in thickness and creaminess among the samples tested, what will be of great use in formulating low fat milk beverages.

1. INTRODUCTION

Inulin is a natural component of several fruits and vegetables, although it is mainly obtained industrially from chicory roots. Native inulin is a mixture of oligomer and polymer chains with a variable number of fructose molecules, joined by β bonds (2→1), which also usually includes a glucose molecule at the end of the chain. It is precisely the β configuration of the anomeric C2 in their fructose monomers that grants inulin its character as a dietetic fibre (Flamm *et al.* 2001), because it is this that makes the inulin resistant to hydrolysis in the small intestine because the digestive enzymes acting on it are specific for alpha-glycosidic bonds. Inulin is considered not as an additive but as a natural and safe nourishing ingredient, and is also considered as GRAS (Generally Recognized as Safe) by the Food and Drug Administration (Coussement 1999; Kaur and Gupta 2002; Milo 2004). The benefits of inulin ingestion include not only those inherent to its condition as a dietetic fibre (reduction of cholesterol and lipid levels in blood, intestinal traffic control, increase in calcium adsorption, etc.) (Flamm *et al.* 2001), but also those derived from its prebiotic nature, related mainly to growth stimulation of health-promoting bacteria (e.g., bifidobacteria) (Roberfroid *et al.* 1998; Roberfroid and Slavin 2000).

In addition to its beneficial effects on health, inulin has interesting functional properties, and can be used as a low-calorie sweetener, fat substitute or texture modifier (Tungland and Meyer 2002). These properties are linked to the degree of polymerization of its chains. The short-chain inulin or oligofructose is much more soluble and sweeter than native inulin, with a sweetness profile similar to that of sucrose and a low caloric content (1-2 kcal/g) but with a lower sweetening power (30-35%). It can be useful to partially replace sucrose in a formulation or to replace it totally when combined with other noncaloric sweeteners. Long-chain inulin, with a high degree of polymerisation (22-25), is more thermally stable, less soluble and more viscous than the native one (Wada *et al.* 2005), and can be used as a fat substitute, with a substitution capacity that is practically double that of native inulin (Franck 2002).

The nutritional and functional characteristics of inulin makes it a very attractive ingredient. In most cases, it is added to different foods to supplement them in order to increase fiber ingestion, in amounts that vary between 3 and 6g per portion, or to assure its bifidogenic nature, adding 3-8g per portion (Coussement 1999). Although a great many commercial products include it in their formulation, there is still little information available regarding its effects on the physical, structural and sensorial characteristics of different types of foods. Some authors have analyzed the effect of adding inulin on the rheological and sensorial characteristics of several dairy products, like ice creams (Schaller-Povolny and Smith 1999, 2001; El-Nagar *et al.* 2002;), yogurts (Dello Staffolo *et al.* 2004; Guven *et al.* 2005), fresh cheese (Koca and Metin 2004; Henelly *et al.* 2006) and dairy desserts (Tárrega and Costell 2006). In most of these works the objective was to use inulin, generally one with a high degree of polymerization, in low-fat food formulations. Some studies have explored the differences in the physicochemical properties of oligofructose and inulins with different degrees of polymerization (de Gennaro *et al.* 2000; Schaller-Povolny *et al.* 2000; Blecker *et al.* 2003); however, there is less information available on the influence of inulins with different degrees of polymerisation on the sensory properties of foods. Recently, Kip *et al.* (2006) analyzed how adding inulins with two different degrees of average polymerization influenced the sensory properties of low-fat yogurt. They observed small differences in viscosity and firmness between the different stirred yogurt samples, while samples containing long-chain inulin were perceived to have a slightly creamier mouthfeel. However, no significant differences were found in the creaminess scores among samples. As stated by the authors, these results may be due to the fact that the sensory profiling used in their work was not sensitive enough to measure significant differences among samples that are not easily distinguishable. According to O'Mahony *et al.* (1979), traditional scaling methods can be used to determine the degree of difference for perceptually large differences; however, for small differences, a food-testing panellist's lack of skill in estimating differences may create enough variance to obscure slight differences. When differences are small, the degree of difference can be measured directly by using the so-called signal detection measures, which are difference tests yielding a direct measurement of the degree of difference (O'Mahony *et al.* 1979; O'Mahony 1983).

The R-index is a short-cut signal detection measure which is applicable to the measurement of slight differences between food stimuli. This index gives the probability that a judge can distinguish a sensory signal from a background noise, the greater the degree of difference, the higher the probability of distinguishing between them (O'Mahony 1983; Vie *et al.* 1991). The applicability of the R-index measure to multiple-difference testing, using rating or ranking data, has been reviewed by Ishii *et al.* (1992), and recently, the R-index has been successfully used to determine the influence of wash-water temperature and chlorine concentration on the sensory properties of cut iceberg lettuce (Delaquis *et al.* 2004), to detect the cooked flavour in pasteurized guava beverages (Argaiz *et al.* 2005), for threshold testing (Robinson *et al.* 2004, 2005), to measure a consumer concept (Lee and O'Mahony 2005) or as a complementary method to monitor individual performance on a taste selection panel (Calviño *et al.* 2005). R-index has also been proposed as an alternative hedonic measure. In this case, it would represent a degree of preference rather than a degree of difference (Vie *et al.* 1991; Cliff *et al.* 1997; O'Mahony *et al.* 2004; Sun *et al.* 2005).

A preliminary work (Villegas and Costell 2006) studied the effects of adding different types of inulin (oligofructose, native and long chain) at different concentrations on the flow behaviour of milk-beverage model systems. The results detected a significant effect of the interaction between inulin concentration and type on flow parameters.

The aims of the present work were (1) to study the effect of adding different types of inulin (short-chain, native and long-chain inulins) at a concentration considered to have a prebiotic effect (6% w/w) on the thickness and creaminess of milk-beverage model systems using the R-index measure, and (2) to explore to what extent each of the three types of inulin can act as a fat replacer by detecting the perceptual differences in thickness and creaminess between the whole-milk samples and the skimmed-milk samples with different concentrations of the three types of added inulin.

2. MATERIALS AND METHODS

2.1. Materials and samples preparation

The assays employed inulin of long average chain length (≥ 23 monomers) (Frutafit TEX!), native (9-12 monomers) (Frutafit IQ) and with a high level of short-chain molecules (2-10 monomers) (Frutafit CLR) from Sensus (Brenntag Química, Valencia, Spain), κ-carrageenan (Satiagel ABN 26, SKW Biosystems, Boulogne Billancourt, France) and skimmed-milk and whole-milk powders (Central Lechera Asturiana, Spain).

Two lots of 10 samples each were prepared: one with whole milk (3.12% fat content) and another with skimmed milk (0.1% fat content). For each lot, a sample without added inulin was prepared as well as samples with different concentrations (6, 8 and 10%, w/w) of each of the three types of inulin. At least two preparations were made for each composition.

The samples were prepared in batches of 800g. Milk powder 12% (w/w) and the corresponding inulin concentrations (0, 6, 8 and 10%, w/w) were dispersed in deionised water at 250rpm, and maintained at 70C for 15 min with the help of a magnetic stirrer and a hot plate (Ared, Velp Scientifica, Usmate, Milano, Italy). κ-carrageenan 0.02% (w/w) was dissolved in deionized water at room temperature for 5 min and then at 70C for 10 min, shaking with a magnetic stirrer at 250rpm. The κ-carrageenan solution was mixed inulin-milk dispersions. Mixing was performed at 250rpm and 70C for 5 min. After the heating process, the evaporated water was replaced gravimetrically. The samples were transferred to a closed flask and then were stored in refrigeration (4±1C) for 24 h before being rheologically and sensorially measured.

2.2. Flow measurements

Flow measurements were carried out in a concentric-cylinder viscometer HAAKE model VT 550 (Termo Haake, Karlsruhe, Germany), using a double gap sensor NV (radii ratio=1.02, length=60mm, gap width=0.35mm) (Thermo Haake) and controlled by the Rheowin Pro software (version 2.93, Haake). Shear stress was determined at shear rates from 1 to 400/s with a ramp of 120s. Two samples of each composition were measured in triplicate at a controlled temperature of 13±1C using a Phoenix P1 Circulator device (Thermo Haake).

Temperature was selected as representative of the usual consumption temperature at sensory analysis. A fresh sample was loaded for each measurement.

Experimental data were fitted to Ostwald- de Waele model (Eq. 1):

$$\sigma = K\dot{\gamma}^{n} \qquad (1)$$

using the Rheowin Pro software (version 2.93, Haake). Where K (mPas^n) is the consistency index and n is the flow index. Because parameter K units depend on n values, to compare samples viscosity, apparent viscosity values at 100/s (η_{100}) were calculated (Eq.2):

$$\eta_{100} = K100^{n-1} \qquad (2)$$

2.3. Sensory analysis

Differences in perception of thickness and creaminess among samples without inulin and those with three different inulin concentrations (6, 8 and 10%) were analyzed using a ranking test (ISO 1988). Sensory analysis was held in a standardized test room with separate booths. A group of 50 untrained panellists evaluated five groups of four samples in different trials. The samples (30 mL) were presented in white plastic cups, coded with random three-digit numbers. Mineral water was provided for mouth-rising. All sessions were carried out in the morning (11:00 a.m.-1:00 p.m.). Data acquisition was performed using Compusense® *five* release 4.6 software (Compusense Inc., Guelph, Canada).

Two sensory experiments were performed. First, the effect of adding 6% of the different types of inulin on the thickness and creaminess perceived was evaluated for both skimmed- and whole-milk samples in two different sessions. In the second experiment, the use of inulin as a fat substitute in milk beverages was evaluated by comparing the thickness and creaminess of the whole-milk sample without added inulin to those of inulin skimmed-milk samples containing different types of inulin added to each of the three concentrations tested (6, 8 and 10%). Three sessions were performed.

2.4. Experimental design and data analysis

To evaluate the effect of adding 6% of the different types of inulin on the flow behaviour of the samples, a factorial design was carried out. The effect of inulin type (three levels), milk type (two levels) and inulin addition (two levels) on the flow index (*n*), and on the apparent viscosity at 100/s (η_{100}) values were analyzed by analysis of variance (ANOVA), including three factors with interactions. To evaluate the potential of the different types of inulin to act as fat replacers, differences in the apparent viscosity at 100/s (η_{100}) values between whole-milk and skimmed-milk samples without added inulin, and skimmed-milk samples with 6, 8 and 10% of each type of inulin were analysed by one-way ANOVA. Least significant differences (LSD) were calculated by the Fisher's test ($P \leq 0.05$). These analyses were performed with Statgraphics Plus 4.1 software (StatPoint Inc., Herndon, VA).

To evaluate the effect of adding 6% of the different types of inulin on thickness and creaminess for both whole-milk and skimmed-milk samples, R-index values were calculated from the ranking data using the equation reported by O'Mahony (1983), and considering the whole-milk and skimmed-milk samples without added inulin as the "noise" for the corresponding group of samples. To measure the degree of difference in thickness and creaminess between whole-milk and skimmed-milk samples with 6, 8 and 10% of each type of inulin, R-index values were also calculated from the ranking data, considering the whole-milk sample without added inulin as the "noise". Statistical significance of each R-index value was determined using the tables reported by Bi and

O'Mahony (1995) with P = 0.05. To determine the effect of adding 6% of the different types of inulin on thickness, a one-tailed test was performed. For the remaining analyses, two-tailed tests were used.

3. RESULTS AND DISCUSSION

3.1. Inulin as a prebiotic ingredient: influence on thickness and creaminess

The prebiotic effect of inulin depends on several factors and especially on the composition of the intestinal flora in each individual. The smaller the amount of bifidobacteria in the flora, the greater is the effect. Given this individual variability, one cannot establish a generally valid dose nor define a direct relationship between the ingestion of inulin and the increase in bifidobacterias (Roberfroid 2005). However, a minimum concentration of 5-7% is considered enough for a food to have a bifidogenic effect. In this case, a concentration of 6% of each of the three types of inulin was selected and their effect on viscosity, thickness and creaminess was studied in two types of milk-beverage model systems, with whole milk and with skimmed milk.

All the milk-beverage samples, both those elaborated with whole milk and those with skimmed milk, displayed pseudoplastic flow behaviour, well fitted to the Ostwald-de Waele model with R^2 values between 0.981 and 0.997. As expected, the whole-milk samples were more viscous, with higher consistency index values (K) and apparent viscosity at 100/s (η_{100}), and displayed a more pseudoplastic flow with lower flow index (n) values (Table 1). The addition of any one of the three types of inulin increased the value of η_{100} in both batches of samples, but had little influence on pseudoplasticity flow.

Table 1. Ostwald-de Waele fit of flow curves for skimmed-milk and whole-milk samples without or with different inulin types. Consistency index (*K*), flow index (*n*) and apparent viscosity at 100/s (η_{100}) average values.*†

Milk type	Flow parameters	Without inulin	With inulin		
			CLR	IQ	TEX!
Skimmed milk	K (mPa s^n)	9.11 (2.64)	11.34 (0.94)	10.95 (0.09)	12.03 (0.68)
	n	0.96 (0.04)	0.94 (0.02)	0.96 (0.001)	0.95 (0.001)
	η_{100} (mPa s)	7.17 (0.79)	8.62 (0.04)	9.08 (0.05)	9.53 (0.55)
Whole milk	K (mPa s^n)	47.52 (1.38)	39.94 (2.81)	41.82 (1.22)	52.51 (7.88)
	n	0.80 (0.01)	0.85 (0.02)	0.85 (0.01)	0.82 (0.03)
	η_{100} (mPa s)	18.67 (0.17)	19.79 (0.02)	20.82 (0.17)	22.81 (0.52)

*Mean values and SDs (in parentheses) of duplicate samples.
†$0.981 \leq R^2 \leq 0.997$.
Inulin types: CLR, short-chain inulin; IQ, native inulin; and TEX!, long-chain inulin.

It seems that the flow behavior of these milk beverages is governed by the structure formed between the κ-carrageenan molecules and the casein micelles without any evidence that inulin aggregates contribute. Probably in these systems, inulin behaves only as a cosolute with the ability to bind water molecules, thus increasing solution viscosity. In general, the apparent viscosity increase on adding any type of inulin was greater in the samples containing skimmed milk, but the viscosity increase in the different model systems also depended on the chain length of the added inulin. In the samples with skimmed milk, this increase varied between 20% when short-chain inulin was added and 32.9 % for long chain; on adding these types of inulin to whole-milk samples, these were between 6 and 22.8%, respectively. Statistical analysis of the effect of the three factors under consideration, i.e., addition of inulin, type of inulin and type of milk, and the interactions among them in terms of flow index values and apparent viscosity at 100/s (Table 2) showed that the interaction between inulin addition and the type of milk (*P*=0.0327) had a significant effect on the flow index value.

Table 2. Effects of milk type, inulin adition and inulin type on *n* and η_{100} values of inulin-milk systems. *F* and *P* values.

Source	*n*		η_{100}	
	F	*P*	*F*	*P*
Main effects				
A. Inulin addition	4.17	0.064	113.73	< 0.001
B. Inulin type	0.42	0.665	9.14	0.004
C. Milk type	220.69	< 0.001	3780.25	< 0.001
Interactions				
AB	0.42	0.665	9.14	0.004
AC	5.83	0.033	2.21	0.163
BC	0.32	0.733	2.77	0.103
ABC	0.32	0.733	2.77	0.103

This indicated that inulin addition did not equally affect the flow pseudoplasticity of the samples with whole milk and skimmed milk. In the samples with whole milk, the inulin decreased flow pseudoplasticity. The value of *n* increased from 0.80 in the sample without inulin to an average value of 0.84 in the samples with inulin. In the skimmed-milk model systems, in which the flow characteristics closely follow Newtonian behavior, no significant difference were found between the values of *n* in the model systems without inulin (*n*=0.96) and those with added inulin (*n*=0.95). The only interaction that significantly affected the value of apparent viscosity at 100/s was the one between inulin addition and type of inulin (*P*=0.0039). The significance of this interaction reflects the different increase in viscosity of the samples on adding each of the three types of inulin. As already mentioned, independent of the type of milk used, the longer the inulin chain length added, the more viscous the sample is (Table 1). The differences in viscosity caused by the types of inulin with different degrees of polymerisation were previously reported by Franck in 2002. In the aforementioned revision of the physicochemical properties of inulin and of oligofructose, this author commented on the different viscosity values of the watery dissolutions of the different types of inulin at a concentration of 5%. The short-chain inulin solution did not reach viscosity of 1mPas, while that corresponding to the long chain was 2.4mPas. Kip *et al.* (2006) verified that adding 3% of long-chain inulin to a low-fat yogurt increased its viscosity more than adding the same concentration of native inulin. Bot *et al.* (2004) also observed a smaller increase in the viscosity of watery dissolutions of native inulin as compared to that observed in the solutions of inulin with a greater degree of polymerization.

Given the small differences between the apparent viscosity values at 100/s among the samples analyzed, it is foreseeable that perceivable differences in their viscosity or creaminess are not easily detectable. The R-index analysis was applied to the mean ranking data in order to evaluate to what extent the differences in the apparent viscosity values (η_{100}), caused by adding the different types of inulin, gave rise to perceivable differences in viscosity and creaminess in the milk-beverage model systems analyzed.

R-indices were calculated for the two batches of samples, giving the degree of difference in thickness and creaminess of each inulin-milk sample as compared to the corresponding milk sample without added inulin (“noise”). Each R-index value indicates the probability of each inulin-milk sample being chosen as thicker or creamier than the corresponding milk sample without inulin, if both were taken in a paired comparison. Figure 1 gives the R-index values for thickness and creaminess obtained for the two batches of samples. It can be seen that all samples with added inulin were significantly perceived as thicker and creamier than the samples without inulin. The R-index critical values for significance at P=0.05 were 61.44% for thickness (one-tailed) and 63.48% for creaminess (two-tailed). For each batch of samples, the R-index values obtained (Fig. 1) indicate the degree of difference in both thickness and creaminess perceived between each inulin-milk sample and corresponding milk sample without added inulin. In this case, it is also interesting to analyze whether there are perceivable differences in viscosity and creaminess between the samples with different types of added inulin. New R-index values were calculated for each pair of samples, considering the reference sample to be the sample with the lowest value of η_{100} in each comparison (Table 1).

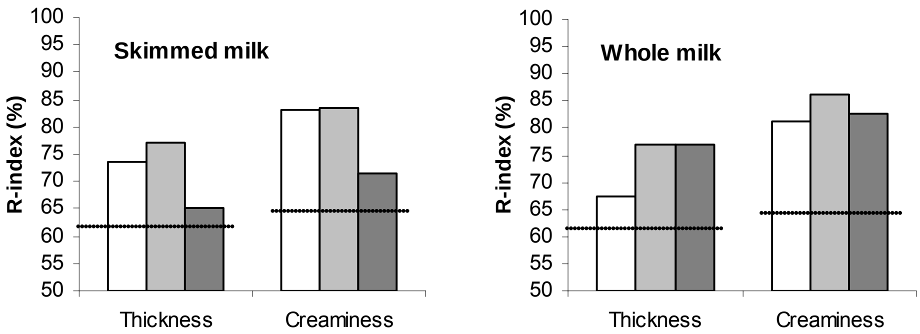

Figure 1. Differences perceived (R-index values) in thickness and in creaminess between samples without inulin added (R-index=50%), and with 6% (w/w) concentration of three types of inulin: average short-chain inulin (▭), native inulin (▭) and average long-chain inulin (▭). Dotted lines (---) indicate the critical values of R-index for thickness, 61.44% (*P*=0.05, one-tailed) and for creaminess, 63.48% (*P*=0.05, two-tailed).

The pairwise R-index values obtained are given in Table 3. From these results, it can be concluded that among the beverages made with skimmed milk, there were only perceptible differences in viscosity between the sample with native inulin and the sample with long-chain inulin, and that the latter was perceived as creamier than the samples with inulin of shorter-chain length. In the whole-milk samples, the only significant difference corresponded to the viscosity perceived between the sample containing short-chain inulin and long-chain inulin.

Table 3. R-index values for thickness and creaminess for all comparisons among inulin-milk model systems of each lot of samples.

Milk type	Sensory attribute	Comparisons*	R-index (%)	Probability† of R-index
Skimmed milk	Thickness	CLR versus IQ	59.58	>0.05
		CLR versus TEX!	57.98	>0.05
		IQ versus TEX!	65.16	>0.01
	Creaminess	CLR versus IQ	52.54	>0.40
		CLR versus TEX!	70.40	<0.002
		IQ versus TEX!	67.14	>0.01
Whole milk	Thickness	CLR versus IQ	61.58	>0.05
		CLR versus TEX!	64.52	>0.01
		IQ versus TEX!	54.54	>0.20
	Creaminess	CLR versus IQ	56.56	>0.20
		CLR versus TEX!	54.70	>0.40
		IQ versus TEX!	51.30	>0.40

*Inulin types: CLR, short-chain inulin; IQ, native inulin; and TEX!, long-chain inulin.
†Values obtained from the table of Bi and O'Mahony (1995).

3.2. Inulin as a fat replacer: influence on thickness and creaminess

One of the most interesting functional properties of inulin, especially long-chain inulin, is the fact it can act as fat mimetic. This property is attributed to its capacity to form microcrystals, which interact with each other forming small aggregates that occlude a great amount of water, creating a fine and creamy texture that provides a mouth sensation similar to that of fat (Franck 2002; Kaur and Gupta 2002; Bot *et al.* 2004). The present work analyzed the differences in apparent viscosity at 100/s value and in thickness and creaminess perceived between whole-milk and skimmed-milk samples with different concentrations of each of the three types of inulin.

All samples showed a shear-thinning flow that fit well to the Ostwald-de Waele model ($0.981 \leq R^2 \leq 0.997$). In Fig. 2, one can compare the flow curves obtained for skimmed-milk samples with different types of inulin added at concentrations of 6, 8 and 10% (w/w) and the flow curves for whole-milk and for skimmed-milk samples without added inulin. As expected, on increasing the inulin concentration, the flow of the skimmed-milk samples became more similar to that of the whole-milk sample. However, it was only when long-chain inulin was added at concentrations between 8 and 10% that a skimmed-milk beverage with a flow similar to that obtained for a whole-milk beverage could be obtained. On analyzing the differences in apparent viscosity at 100/s (η_{100}) of the whole-milk and skimmed-milk samples without added inulin, and those of the skimmed-milk samples with added inulin, using a single-factor ANOVA, all the samples with added inulin were found to have a significantly higher η_{100} value than the skimmed-milk sample without added inulin, and significantly lower than the whole-milk sample without added inulin, except for the sample with long-chain inulin at the maximum concentration assayed (10%), of which the value of η_{100} was significantly higher (Fig. 3).

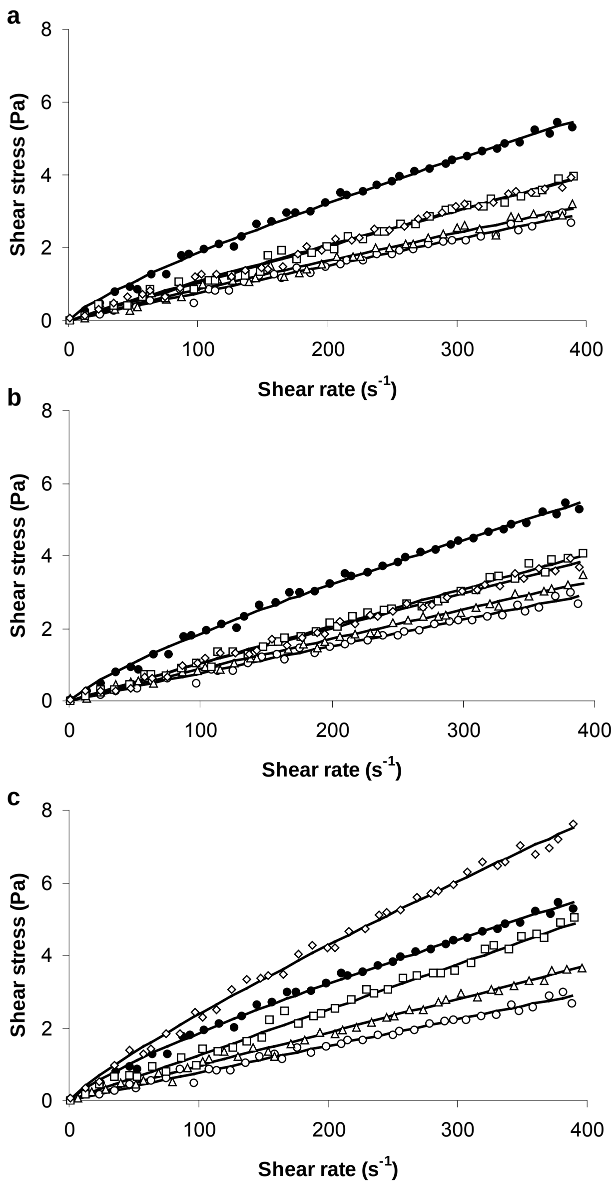

Figure 2. Shear stress-shear rate plots for inulin-milk beverages: skimmed-milk (○) and whole-milk (●) samples without inulin added, skimmed-milk samples with 6 (△), 8 (□) and 10 (◇) of inulin. a) Average short-chain inulin samples. b) Native inulin samples. c) Average long-chain inulin samples. Experimental points and model fitting curves. Measurements at 13±1C.

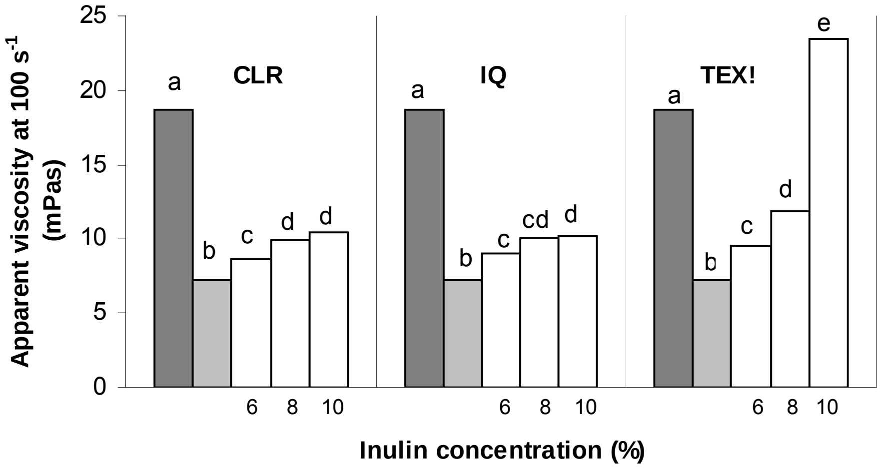

Figure 3. Effect of the addition of three types of inulin: average short-chain inulin (CLR), native inulin (IQ) and average long-chain inulin (TEX!) at different concentrations (6, 8, 10%, w/w) on the apparent viscosity at 100/s (η_{100}) values of skimmed-milk samples (▭), skimmed-milk (▭) and whole-milk (▭) samples without inulin. Different letter on top of bars means significant differences (*P*≤ 0.05).

To measure the degree of difference in thickness and creaminess between whole-milk and skimmed-milk samples with 6, 8 and 10% of each type of inulin, R-index values were also calculated from ranking data, and considered the whole-milk sample without inulin added as the “noise”. In this case, each R-index value indicated the probability that each inulin-skimmed-milk sample had of being chosen as more or less thick or creamy than the corresponding whole-milk sample without inulin, if both were presented in a paired-comparison test. The R-index values obtained for thickness and creaminess and their statistical significance for the samples analyzed are given in Table 4.

Independent of the degree of inulin polymerization, when a concentration of 6% was added to skimmed milk, the milk beverages were perceived to be less viscous and less creamy than the sample with whole milk. When concentrations of 8% were added, the three samples with different types of inulin were again perceived as less viscous than the whole-milk sample; however, the samples with long-chain or short-chain inulin did not differ in creaminess from the whole-milk sample. The influence of chain length on the fat-substitute potential of inulin in milk beverages was accentuated on increasing the added concentration up to 10%. The viscosity of the sample with 10% of long-chain inulin did not differ from the viscosity of the sample with whole milk, and was significantly perceived to be creamier.

Table 4. Differences perceived in thickness and in creaminess between reference sample (whole-milk sample without inulin added) and skimmed-milk samples with different concentrations of each type of inulin added. R-index values*.

Sensory attribute	Inulin type	Concentration of inulin (%)		
		6	8	10
Thickness	CLR	77.56 (<0.05)	75.60 (<0.05)	65.04 (<0.05)
	IQ	82.46 (<0.05)	75.18 (<0.05)	68.74 (<0.05)
	TEX!	81.98 (<0.05)	71.14 (<0.05)	53.78 (>0.05)
Creaminess	CLR	79.36 (<0.05)	62.84 (>0.05)	57.70 (>0.05)
	IQ	79.02 (<0.05)	66.40 (<0.05)	55.20 (>0.05)
	TEX!	85.14 (<0.05)	62.76 (>0.05)	65.34 (<0.05)

*Probability of R-index values between parentheses (Bi and Mahony 1995)
CLR, short-chain inulin; IQ, native inulin; TEX!, long-chain inulin.

4. CONCLUSIONS

The results indicate that adding inulin of different degrees of polymerization, at a high-enough concentration for these drinks to have a prebiotic effect (6% w/w), slightly increased the values of their apparent viscosity at 100/s. Applying the R-index analysis to mean ranking data helped detect the small perceivable differences in thickness and creaminess among the samples tested. The potential of the different types of inulin (short chain, native and long chain) to act as fat substitutes also depended on chain length, as well as on the concentration of added inulin. With respect to the interval of concentrations considered in this work, it was necessary to add long-chain inulin at concentrations of over 8% in order to obtain low-fat milk beverages with a thickness and creaminess similar to those perceived for whole-milk beverage. At lower concentrations (6 and 8%), the three types of inulin used in these assays provided milk beverages with a significantly lower thickness than that corresponding to whole-milk beverage.

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CAPÍTULO 6

OPTIMISING ACCEPTABILITY OF NEW PREBIOTIC LOW-FAT MILK BEVERAGES

ABSTRACT

The main purpose of the present work was to optimise the acceptability of two low fat milk beverages with different types of inulin (oligofructose – CLR and long-chain inulin –TEX!) using Response Surface Methodology. Sixteen formulations of beverage with each inulin type were obtained, varying inulin concentration from 3 to 8%, and sucrose concentration from 0 to 8%. Fixed amounts of vanilla aroma (0.03%), colorant (0.1%) and skimmed-milk powder (12%) were used. A group of 50 consumers evaluated the acceptability of the samples using the 9-point hedonic scale and tested the appropriateness of some sensory attributes intensity (colour, vanilla flavour, sweetness and thickness) using 5-point Just About Right scales. Response surface plots showed that formulations containing 5-8 % CLR and 4-6.5% sucrose and formulations containing 4-6.5% for both TEX! inulin and sucrose were located in the optimum region. The sweetness and, to a lesser extent, the thickness were the attributes that most affected the acceptability of the samples. The low fat samples selected as the optimum for each inulin type (4% sucrose and 7% CLR inulin; 5.2 sucrose and 5.5 TEX! inulin) showed no differences in acceptability (α = 0.05) between them and they showed no differences in acceptability when compared with a full fat control sample.

Keywords: response surface, acceptability, prebiotic beverages, optimization

1. INTRODUCTION

Functional foods have a high growth potential (Sloan, 2006) although their market is characterized by a high proportion of products that fail commercially. This failure, as commented by Fogliano and Vitaglione (2005), is only partially explicable by the intrinsic risk associated to the commercialization of this type of product. In fact, in many cases, it is easy to detect important errors in the design and development of functional foods that could have been avoided by using better strategies. It is evident that the identification of new bioactive compounds is important in functional-food design. But the real value of each one will firstly depend, on the amount of compound that the consumer needs to include in his/her diet for it to be beneficial to health, and also, that the characteristics of the food matrix, to which the compound is incorporated, do not alter the stability and bioavailability of the active principle in the final product (Clydesdale, 2004). Even while considering and controlling these aspects, the success of a functional food will depend on whether it responds to consumer needs and on the degree of satisfaction that it is able to provide (Urala & Lähtennmäki, 2004; Heldman, 2004). For that reason, the consumer's response must be taken into consideration, not only to evaluate the acceptance of the final product, but also from the beginning of the process and its development. Sensory evaluation by consumers is important in product development itself for new-product development guidance, product improvement and optimization (Choi, Phillips, & Resurreccion, 2007). Consumer-orientated product optimization brings the consumer into the product development at an early stage. Response Surface Methodology is a useful tool for optimising sensory quality of foods. Following appropriate statistical designs, the experimental data relate variations in responses to variations in previously selected factors (Gacula, 1993; Khuri & Cornell, 1987; Damasio, Costell, & Duran, 1999). An optimal formulation maximises consumer acceptance in that it is the best possible formulation given a fixed set of ingredients (Fishken, 1983; Pastor, Costell, Izquierdo, & Duran, 1996; Damasio et al., 1999; Gan, Karim, Muhammad, Bakar, Hashim, & Rahman, 2006; Acosta, Víquez, & Cubero, 2008). When conducting this type of study, one must take into account that there is no cause-effect connection between the independent factors (ingredients) controlled by the experimenter and the dependant factor (acceptability), and it is necessary to analyse to what extent could a possible interaction between the ingredients cause perceptible variations of the sensory features and if any such variations affect the acceptability. The Just About Right scales can play a diagnostic role to determine how the consumer feels the product (Gacula, Mohan, Faller, Pollack, & Moskowitz, 2008).

Inulin and oligofructose are considered as safe nourishing ingredients (Coussement, 1999; Kaur & Gupta, 2002). Native inulin is a mixture of oligomer and polymer chains with a variable number of fructose molecules, joined by β bonds (2→1), which also usually include a glucose molecule at the end of the chain. The degree of polymerization of the chains oscillates between 2 and 60 units and the degree of average polymerization is approximately 12. By means of partial enzymatic hydrolysis of the native inulin with endo-inulinase, oligofructose, with a polymerization degree that oscillates between 2 and 7 and whose average value is of 4, can be obtained. By applying physical methods (ultrafiltration, crystallization, etc.), a long-chain inulin with a degree of average polymerization that oscillates between 22 and 25 is obtained (Franck, 2002; Moerman, Van Leeuwen, & Delcour, 2004). The ingestion of inulin can not only provide the benefits inherent to its condition as a dietetic fibre due to the β configuration of the anomeric C2 in its fructose monomers, but also those deriving from its prebiotic nature, related mainly to the stimulation of bifida-bacterial growth (Roberfroid, Van Loo,

& Gibson, 1998; Roberfroid & Slavin, 2000) and to diminishing the growth of bacteria belonging to fusobacteria and clostridia (Kaur & Gupta, 2002). In most cases, its addition to different foods has aimed to supplement them in order to increase fibre ingestion, in amounts that oscillate between 3-6 g per portion, or to assure its bifidogenic nature, adding 3-8 g per portion (Coussement, 1999). Moreover, the prebiotic effect of inulin depends mainly on the composition of the intestinal flora in each individual and on the degree of polymerization of fructose-chains (Coudray, Tressol, Gueux, & Raysiguier, 2003; Biedrzycka & Bielecka, 2004; Abrams et al., 2005).

In addition to its beneficial effects on health, inulin has interesting technological properties, as a low-calorie sweetener, fat substitute, or due to its capacity to modify texture (Tungland & Meyer, 2002). These properties are also linked to the degree of polymerization of its chains. The short chain or oligofructose is much more soluble and sweeter than native inulin, with a sweetness profile similar to that of saccharose and low caloric content (1-2 Kcal/g) although with an inferior sweetening power (30-35%). Long-chain inulin, with a high degree of polymerization (22-25), is thermally more stable, less soluble and more viscous than the native one (Wada, Sugatani, Terada, Ohguchi, & Miwa, 2005), and can be used as a fat substitute, "*as fat mimetic*", with a capacity that is practically double that of native inulin (Voragen, 1998; Coussement, 1999). Its properties as a fat substitute are attributed to its capacity to form microcrystals that interact with each other forming small aggregates that occlude a great amount of water, creating a fine and creamy texture that provides a buccal sensation similar to that of fat (Frank, 2002; Kaur et al., 2002; Bot, Erle, Vreeker, & Agterof, 2004).

Some authors have analysed the effect of adding inulin on the rheological and sensorial characteristics of several dairy products, like ice-creams

(El-Nagar, Clowes, Tudorica, Kuri, & Brennan, 2002; Schaller-Povolny & Smith, 1999 and 2001), yoghurts (El-Nagar et al., 2002; Dello Staffolo, Bertola, Martino, & Bevilacqua, 2004; Guven, Yasar, Karaca, & Hayaloglu, 2005; Brennan & Tudorica, 2007), fresh cheese (Koka & Metin, 2004; Henelly, Dunne, O'Sullivan, & O'Riordan, 2006) and dairy desserts (Tárrega & Costell, 2006; Cardarelli, Buriti, Castro, & Saad, 2008). In most of these works the objective was to use one type of inulin, generally one with a high degree of polymerisation, as a fat replacer in low-fat food formulations. There is less information about the effect of inulins with different degrees of polymerization on the rheological and sensory properties of dairy products. González-Tomás, Coll-Marqués, and Costell (2007) pointed out that the effect of the inulin type and concentration (from 2.5 to 7.5%) had little impact on the viscoelasticity of whole-milk desserts, but they were key factors in skimmed-milk desserts, and Aryana, Plauche, Rao McGrew, and Shah (2008) showed that the addition of 1.5% of inulin of different chain length did not affect the colour and viscosity of fat-free yoghurts. Preliminary works (Villegas & Costell, 2007; Villegas, Carbonell, & Costell, 2007) analysed the effects of adding different types of inulin (oligofructose, native and long chain) at different concentrations on the flow behaviour and on the perceived thickness and creaminess of milk-beverage model systems. Results detected a significant effect of the interaction between inulin concentration and average chain lengths on flow and sensory parameters.

The aims of the current work were: 1) to compare the effect of two inulins with different chain lengths (short and long) at different concentrations (from 3 to 8%) on physicochemical properties, sensory intensity evaluated by consumers with just about right scales and acceptability of low fat milk beverages, and 2) to optimise the acceptability of prebiotic low fat milk beverage formulations containing either short or long inulins using Response Surface Methodology.

2. MATERIALS AND METHODS

2.1. Samples composition and preparation

Vanilla milk beverages were prepared using two types of inulin: inulin with high level of short-chain molecules (2-10 monomers, Frutafit CLR) and inulin of long chain length (≥ 23 monomers, Frutafit TEX!) from Sensus (Brenntag Química, Spain). Samples also contained the following ingredients: skimmed-milk powder (0.1% fat content; Central Lechera Asturiana, Spain), commercial sucrose, vanilla aroma 18793A (Lucta S.A.) and colorant A-320WS (CHR Hansen S.A.).

For the optimisation study, two separate batches of beverages were prepared for each type of inulin with varying sucrose and inulin concentrations. Basic sample composition was selected according to a two-factor central composite rotatable design with replicates of the central point for estimating the pure error (Gacula, 1993). It comprised 16 points: four factorial, four axial, and eight central points, with a design radius α = 2 (Table 1).

Table 1. Basic experimental design. Coded and uncoded values of levels and composition

Formulation	Coded level		Uncoded level	
	Sucrose	Inulin	Sucrose %(w/w)	Inulin %(w/w)
1	-1	-1	2	4.25
2	1	-1	6	4.25
3	-1	1	2	6.75
4	1	1	6	6.75
5	-2	0	0	5.5
6	2	0	8	5.5
7	0	-2	4	3
8	0	2	4	8
9-16	0	0	4	5.5

Concentration ranges for ingredients were selected according to information about the bifidogenic nature of inulin and to the results obtained in previous works. Concentration range for inulins, from 3 to 8% (w/w) was selected in accordance with the proposal of Coussement (1999) and with the information obtained about the influence of inulin average chain length on flow behaviour and on thickness and creaminess perceived in milk beverages (Villegas & Costell, 2007; Villegas et al., 2007). Concentration range for sucrose, from 0 to 8% (w/w), was selected on the basis of the soluble solids (ºBrix) contained in commercial samples of vanilla beverages (Villegas, Carbonell, & Costell, 2008).

Vanilla milk beverages were prepared in batches of 900g. Skimmed-milk powder 12% (w/w), inulin and sucrose were dispersed in mineral water at 250rpm with the help of a magnetic stirrer and a hot plate (Ared, Velp Scientifica). When temperature rose to 70ºC, colorant 0.1% (w/w) was added and temperature was maintained for 5 minutes. Samples were cooled down at room temperature. Then, vanilla aroma 0.03% (w/w) was added and evaporated water replaced gravimetrically. Finally, samples were transferred to closed flasks and stored in refrigeration (4±1ºC) for 24 hours before being evaluated. Two replicates of each formulation were prepared.

For the verification study, a whole-milk sample (3.12% fat content) was prepared with whole-milk powder at 12% (w/w), sucrose 6% (w/w), colorant 0.1% (w/w) and vanilla aroma 0.03% (w/w) in the same manner as explained previously.

2.2. Soluble solids and pH

Soluble solids were determined in a digital refractometer (ATAGO RX-100) at room temperature and the results expressed in degrees Brix at 20ºC. A digital pH meter (GLP 21, Crison) was used to measure pH at room temperature. Both measurements were taken in duplicate for each sample.

2.3. Colour measurements

Colour of samples was measured in a Konica Minolta CM-3500d spectrophotometer (Konica Minolta Sensing Inc., Japan). Samples were held in optical glass cells 3.8 cm high and 6 cm diameter. A 3.5 cm thick layer was covered with the white standard plate (X = 78.50; Y = 83.32; Z = 87.94) for measurement of diffused reflected light from the cell bottom using a 13 mm aperture. Reflection spectra were registered and results were given in CIELAB system for illuminant D65 and a 10º angle of vision. Registered parameters were: L* (brightness), a* (red component), b* (yellow component), C* (chroma) and h (hue). All samples were measured in duplicate.

2.4. Flow measurements

Flow measurements were carried out in a viscometer Haake model VT 550, using a double gap sensor NV (radii ratio = 1.02, length = 60 mm, gap width = 0.35 mm) (Thermo Haake, Karlsruhe, Germany) and controlled by the Rheowin Pro software. Flow curves were obtained by recording shear stress values (σ) when shearing the samples at increasing shear rates ($\dot{\gamma}$), from 1 to 600 s^{-1} with a ramp of 120 s. Samples were measured in duplicate at a controlled temperature of 10 ±

1ºC using a Phoenix P1 Circulator device (Thermo Haake, Karlsruhe, Germany). Temperature was selected as representative of the usual consumption temperature for sensory analysis. A fresh sample was loaded for each measurement.

Experimental data were fitted to the Newton model equation ($\sigma = \eta\dot{\gamma}$) using Rheowin Pro data software (version 3.40, Haake).

2.5. Sensory evaluation

Sensory tests were carried out in a standardised test room (ISO 2007) in morning sessions. Samples (30 mL) were served at 10 ± 1ºC in white plastic cups coded with random three-digit numbers and mineral water was provided for mouth-rinsing.

The optimisation study was performed by 50 consumers, recruited from IATA staff. Each consumer evaluated first the overall acceptability of each one of the 16 formulations obtained for each type of inulin. For each batch, four samples per session over four sessions, using a 9-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”) were evaluated. The consumers also evaluated the level of suitability of colour, sweetness, vanilla flavour and thickness using a 5-point just about right (JAR) scale (1 = too weak, 3 = just about right; 5 = too strong). That procedure allowed to determine how much the sample varied or approached the attribute considered to be ideal for the milk beverage.

In order to reduce the possible impact of serving order, particularly the error due to the influence of the characteristics of the first sample on the evaluation of the subsequent samples, one sample corresponding to the central point of the design (samples 9 to 16, Table 1) was served first in each session. The other three samples evaluated in each session were served following a Williams design for three samples (MacFie, Bratchell, Greenhoff, & Vallis, 1989). Samples were presented monadically.

For the verification study, a preference study was carried out by 75 consumers recruited from IATA staff using the paired comparison test (ISO, 2005). Each consumer evaluated three pairs of samples: whole milk sample with each one of both optimum formulations and both optimum formulations between them. In order to reduce the possible effect of the serving order, for each pair of samples an equal number of consumers received a different sample first. Data acquisition was performed using Compusense® five release 4.6 software (Compusense Inc., Guelph, Ontario, Canada).

2.6. Analysis of data

Two way analyses of variance (ANOVA) with interaction were performed on instrumental parameters and acceptability data in order to study the effects of both inulin type and formulation. XLSTAT-Pro Version 2007 (Addinsoft, Paris, France) was used.

For analysing data obtained from JAR scale first, the percentage of consumers who perceive the sample attributes in a certain way was calculated. Secondly, the approach proposed by Gacula, Rutenbeck, Pollack, Resurreccion and Moskowitz (2007) based on estimating below and above deviations from the point 3 of the scale (JAR) was used. Individual JAR scale scores (1, 2, 3 ,4 or 5) were transformed into (-2, -1, 0, 1 or 2, respectively). Two groups of data emerge from this calculation, one for those consumers who feel that the sample has too little of the attribute (below the JAR) and another for those consumers who feel that the product has too much of the attribute (above the JAR). The values below the JAR point 3 corresponded to the negative deviation value (too little of the attribute) and the values above the JAR point correspond to the positive deviation value (too much of the attribute). Plots of acceptability versus JAR deviation values were used to study the relationship between acceptability and the intensity of each attribute.

In the optimisation study, the results were analysed using response surface methodology (RSM) (Gacula, 1993). Overall acceptability data were submitted to a multivariate regression analysis and fitted to a second order model equation provided in the design:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_{11} X_1^2 + B_{22} X_2^2 + B_{12} X_{12} + Error \qquad \text{(Eq. 1)}$$

where Y is the overall acceptability, B_0 is the intercept (constant), B_1, B_2, the linear, B_{11}, B_{22} the quadratic and B_{12} the interaction effects, X_1 and X_2 the independent variables and the random error component. To prepare the adjusted models and their respective surfaces, only the statistically significant parameters at $P \leq 0.05$ were considered based on Student's test. ANOVA of the regression equation allowed the calculation of goodness of fit and of significance of the linear, quadratic and interaction effects.

The validity of the models was evaluated as a function of their respective coefficients of determination (R^2) as well as by an analysis of the lack of fit. These analyses were performed with the SPSS 13.0 software.

Results of the paired comparisons of the verification study were analysed using binomial statistics for two-tailed alternate hypothesis (α = 0.05) using Compusense® five release 4.6 software.

3. RESULTS AND DISCUSSION

3.1. Influence of inulin average chain length on physicochemical properties, acceptability and sensory attributes appropriateness of low-fat milk beverages

Analysis of variance was used to analyse the effect of inulin average chain length and of low-fat milk beverage formulation as well as the interaction between them on soluble solids content, pH, colour, viscosity and acceptability of beverages. The effect of inulin type was significant for all of them except for pH (Table 2). For soluble solids content, brightness, viscosity and acceptability a significant interaction between the two factors indicated that the effect of either type of inulins on those variables was different for the different formulations.

Soluble solids content values varied significantly depending on the formulation and on the inulin type, ranging from 17.8 to 26% for samples with CLR inulin and from 17.8 to 24.8 for samples with TEX! inulin (Fig. 1a). When a low amount of inulin was added (3 and 4.5%; samples 1, 2 and 7), no significative differences were found in the samples containing each inulin type, irrespective of the amount of sucrose added. In samples 3, 4 and 8, containing higher concentrations of inulin (6.75 and 8%), the soluble solids content of the samples with CLR inulin was significantly higher than those with TEX! inulin, likewise this was irrespective of the amount of sucrose in the formulation. For samples with 5.5% of inulin, the significance of the differences in soluble solids content between the two batches of samples (samples 5, 6 and 9) depended on the sucrose concentration. The higher the sucrose content, greater the difference between the CLR inulin and TEX! inulin samples. The increase of soluble solids due to inulin addition was higher for CLR inulin than for TEX!. This is due to the fact that CLR inulin contains a higher proportion of mono and disaccharides than TEX!

inulin.

Table 2. Two way analyses of variance with interactions for physicochemical and acceptability data

Parameter	Source	*F*-ratio	*P*-value
Soluble solids (%)	Type of inulin	107.856	< 0.0001
	Formulation	270.999	< 0.0001
	Type of inulin*formulation	8.848	< 0.0001
Viscosity (mPas)	Type of inulin	187.641	< 0.0001
	Formulation	69.556	< 0.0001
	Type of inulin*formulation	9.762	< 0.0001
pH	Type of inulin	0.484	0.496
	Formulation	2.832	0.032
	Type of inulin*formulation	2.827	0.032
L*	Type of inulin	31.671	< 0.0001
	Formulation	1.686	0.170
	Type of inulin*formulation	7.196	< 0.001
a*	Type of inulin	88.011	< 0.0001
	Formulation	4.213	0.005
	Type of inulin*formulation	0.573	0.787
b*	Type of inulin	106.517	< 0.0001
	Formulation	5.119	0.002
	Type of inulin*formulation	1.583	0.199
Acceptability	Type of inulin	27.159	< 0.0001
	Formulation	44.790	< 0.0001
	Type of inulin*formulation	2.068	0.037

As expected (Villegas & Costell, 2007), flow behaviour of samples was newtonian ($0.976 \le R^2 \le 0.991$ and $0.975 \le R^2 \le 0.993$, for CLR and TEX! samples respectively). In general, the TEX! samples had a higher viscosity (5.30-8.92 mPas) than the CLR samples (4.91-6.66 mPas) (Fig.1b) and differences increased when increasing the inulin concentration. Differences in viscosity between samples with equivalent formulation and different type of inulin, were only significant for inulin concentrations of 5.5% or more.

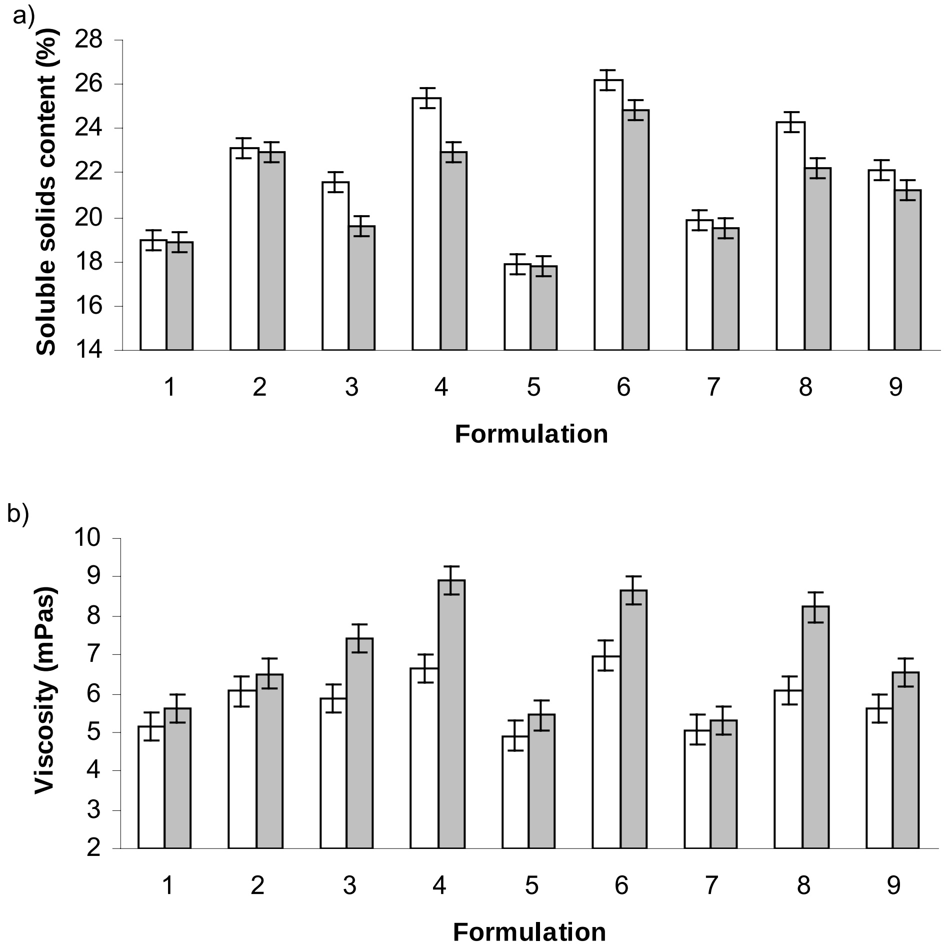
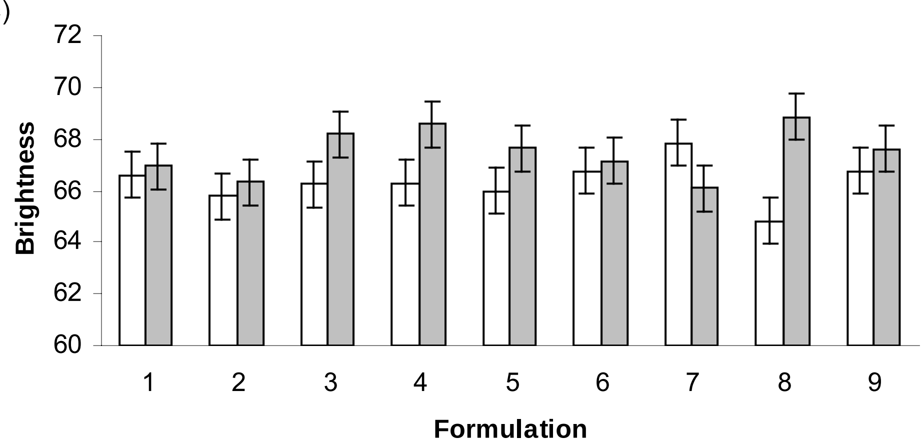


Figure 1a and 1b. Effect of the inulin type, CLR ( ) and TEX! ( ), on a) soluble solids content and b) instrumental viscosity, of different samples. Identification of samples formulation in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16).

Instrumental colour of samples was characterized by L*, a* and b* parameters. Samples with CLR inulin added had significantly slightly lower values for a* and b* than the samples with TEX! inulin. Only for L* values, that ranged from 64.8 to 67.8 for samples with CLR inulin and from 66.1 to 68.83 for samples with TEX! inulin, the effect of the interaction between the two factors considered was significant. Samples with TEX! inulin added were with higher L* values although only for samples with higher inulin concentrations the differences on brightness between CLR and TEX! samples were significant (Fig. 1c).

Analysis of variance of overall acceptability scores showed that differences in acceptability of samples were mainly attributed to the formulation ($P < 0.001$) but also to the inulin type ($P < 0.001$) and that the interaction between these factors were significant (Table 2). Acceptability levels were slightly higher for CLR inulin samples (between 3.5 and 6.4) than for the TEX! inulin samples (between 2.7 and 6.2) (Fig. 1d), but the difference was only significant for formulations with 2% sucrose and 4.25% inulin (formulation 1, Table 1).

c)



d)

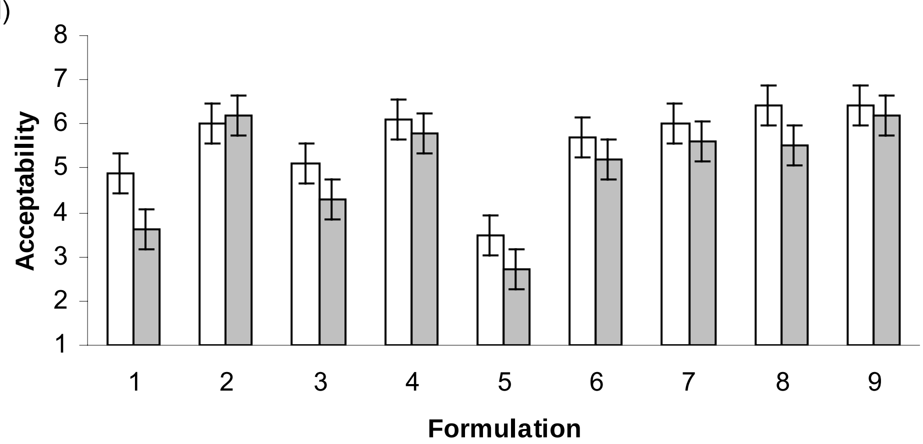
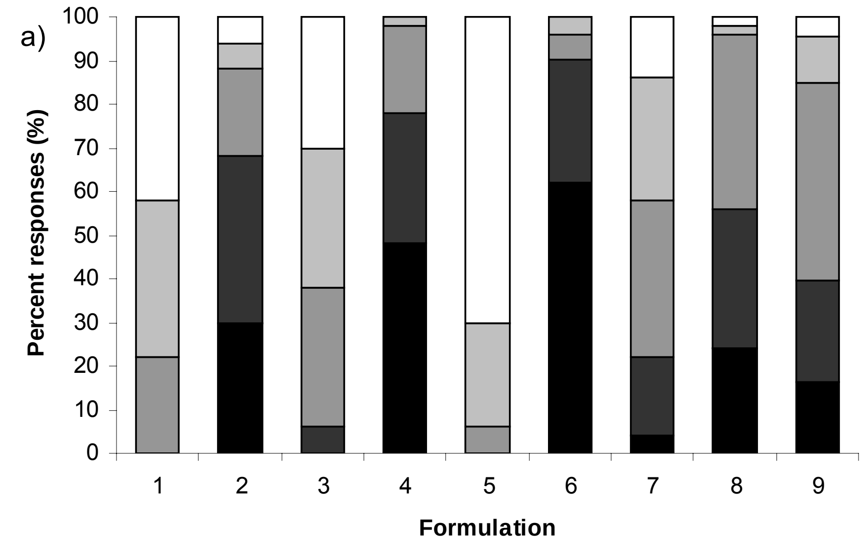


Figure 1c and 1d. Effect of the inulin type, CLR (▭) and TEX! (▭), on c) brightness and d) acceptability, of different samples. Identification of samples formulation in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16).

The JAR scales are used to assess the appropriateness of specific sensory attribute levels. The data obtained with these scales provide an idea of the proportion of consumers who perceive each sample in a certain way. As rules of thumb, to conclude that a specific attribute is at its optimal level, a minimum of 70% of the responses are usually expected to be in the “just about right" group and to conclude that an attribute is not at its optimal level, a minimum of 20% of consumers is usually needed in the "too weak" or "too strong" categories (Meullenet, Xiong, & Findlay, 2007). According to the results obtained, all samples formulated with CLR inulin can be considered to have an optimal colour level. The percentage of consumers that consider the samples' colour "just about right" is over 79% except for sample 5 (68%). For samples including TEX! inulin, five of them (samples 1, 2, 3, 6 and 9) can also be considered to have optimal colour (70-82% of just about right responses). For the rest of samples, the percentage of responses were lower (60-68%). In any case, for all of the samples with below 70% of just about right responses, the responses in the "too weak" or "too strong" categories were lower than 10%. A higher variability was detected on the appropriateness of the level of sweetness, vanilla flavour and thickness due to sample formulation and inulin type.

When comparing samples with the same formulation and with a different inulin type added, it was observed that regarding those in which the sucrose added was over 2%, the percentage of consumers perceiving the samples as excessively sweet or slightly sweeter was greater for samples with CLR inulin than those with TEX! inulin (Fig. 3). Regarding the intensity of the vanilla flavour, and with the exception of the formulations 1, 3 and 5, in which the percentage of "too weak" responses to samples containing both types of inulin was very high (30-85% for samples with CLR inulin and 65-90% for those with TEX! inulin), the percentage of consumers finding the vanilla flavour in the remaining formulations just about right was greater for samples with CLR inulin than for those with TEX! inulin (Fig. 4). Only two of the samples with CLR inulin (formulations 4 and 7) can be considered to have an optimal vanilla flavour intensity (82% of just about right responses), whereas the percentage of just about right responses for the samples with TEX! inulin was never more than 60%. The difference in the percentage of consumers finding the viscosity of the different formulations just about right was usually greater regarding samples with CLR inulin, except the formulation 2. (Fig. 5). These results show that depending on the composition of the vanilla beverage samples, the addition of inulins with a different average chain length can produce products whose sensorial differences are clearly perceived by the consumer.



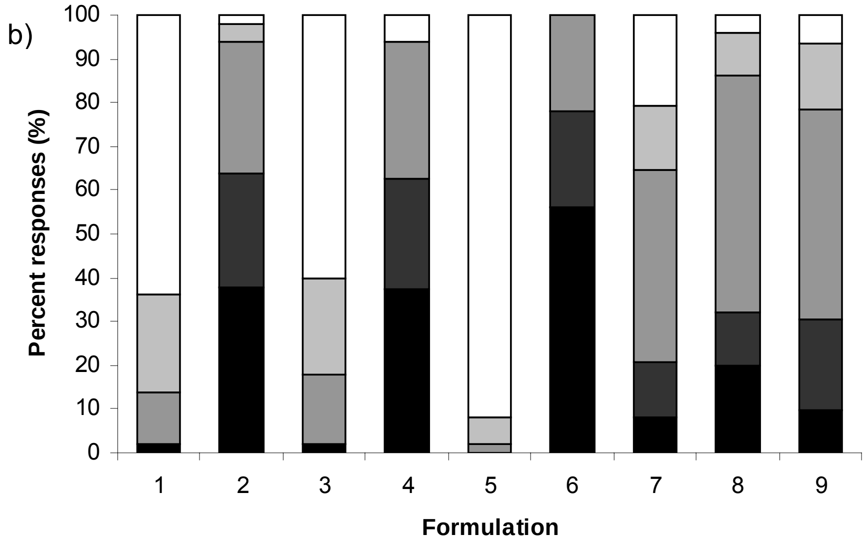


Figure 3. Consumer assessments distribution about the appropriateness of sweetness intensity using the 5-point just about right scale: too weak ( ), weak ( ), just about right ( ), strong ( ), too strong ( ). a) CLR inulin samples and b) TEX! inulin samples. Composition of formulations in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16).

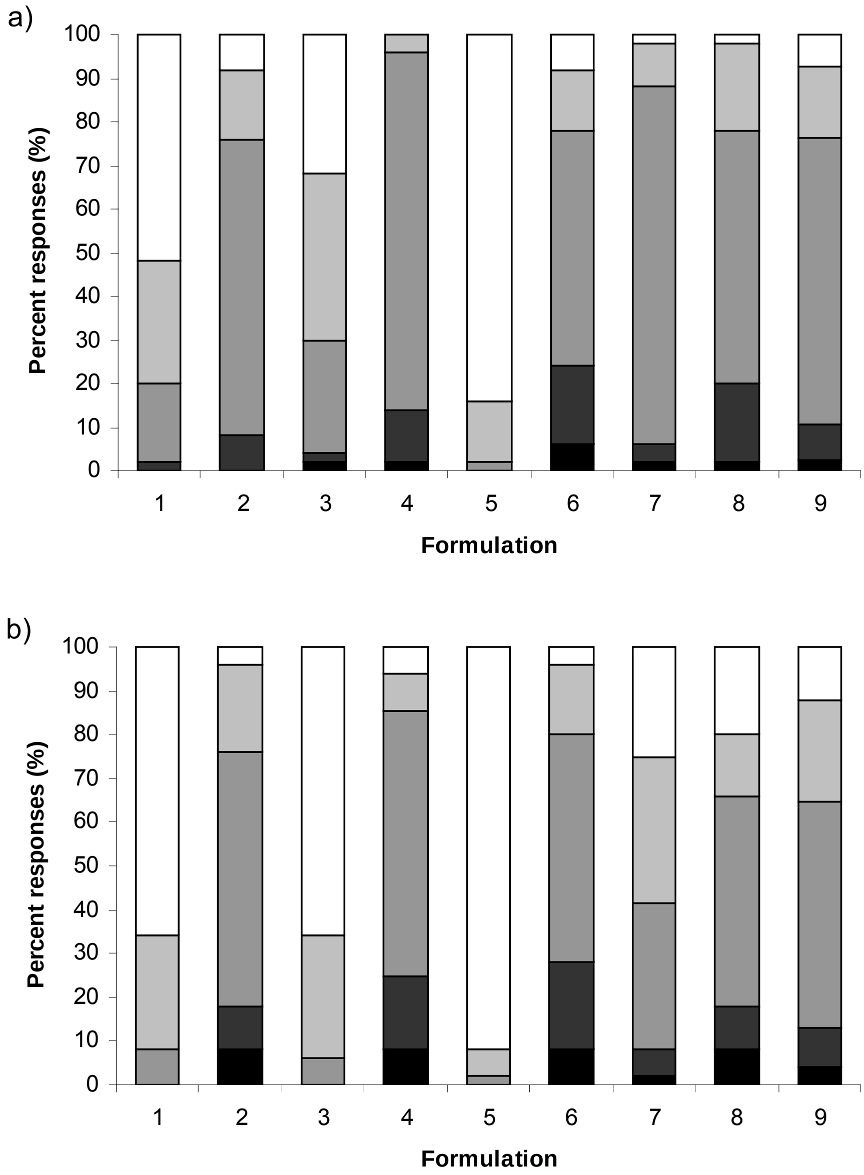


Figure 4. Consumer assessments distribution about the appropriateness of vanilla flavour intensity using the 5-point just about right scale: too weak ( ), weak ( ), just about right ( ), strong ( ), too strong ( ). a) CLR inulin samples and b) TEX! inulin samples. Composition of formulations in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16).

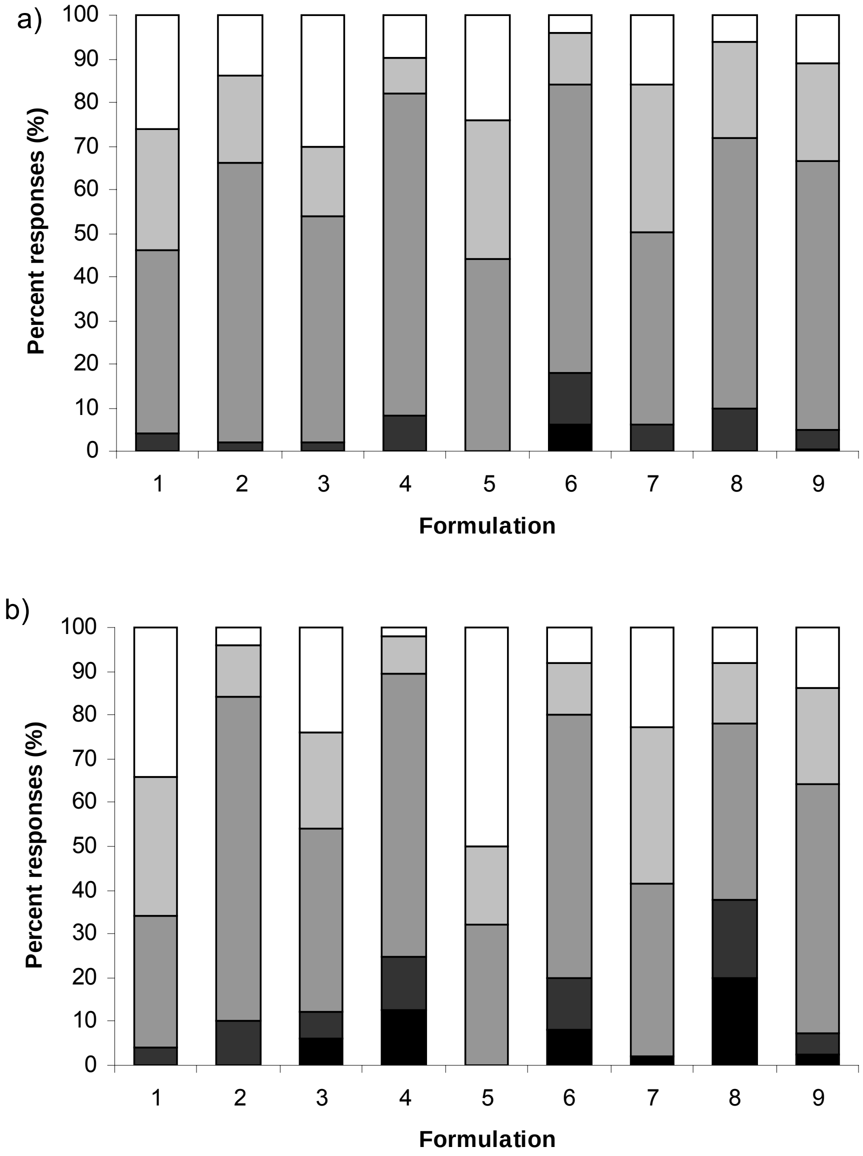


Figure 5. Consumer assessments distribution about the appropriateness of thickness intensity using the 5-point just about right scale: too weak ( ), weak ( ), just about right ( ), strong ( ), too strong ( ). a) CLR inulin samples and b) TEX! inulin samples. Composition of formulations in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16).

In order to analyse the relationship between the overall acceptability of samples and the appropriateness of each attribute levels, plots of acceptability versus JAR score deviation from category 3 (the just about right anchor of the scale) were used (Gacula et al., 2007). Two groups of data will emerge from this calculation, one for those individuals who feel that the product has too little of the attribute (below the JAR), and the other for those individuals who feel that the product has too much of the attribute (above the JAR).

According to the results obtained, no consistent relations between colour and overall acceptability for both, samples with CLR or with TEX! inulins, were detected (Fig. 6a and Fig. 7a, respectively). Slight differences in colour, instrumentally measured, in the different formulations and the low percentage of responses in the “too weak” or “too strong” categories, hardly affected the overall acceptability of the samples.

A stronger relation between vanilla flavour and sweetness appropriateness and overall liking can be observed for both CLR and TEX! samples (Figs. 6b,c and 7b,c). Samples perceived by most of consumers as with less vanilla flavour and with less sweetness (samples 1, 3 and specially, sample 5), and the sample with a higher percentage of “too sweet” responses (sample 6), had a lower acceptability. Samples perceived by an important number of consumers as having less thickness (1, 3 and 5) (Fig. 5) also had a lower acceptability (Figs. 6d and 7d).

It can be concluded that for these types of beverages, the sweetness and, to a lesser extent, the thickness were the attributes that most affected the acceptability of the samples, and therefore, the effect of inulin addition on acceptability will depend on its average chain length.

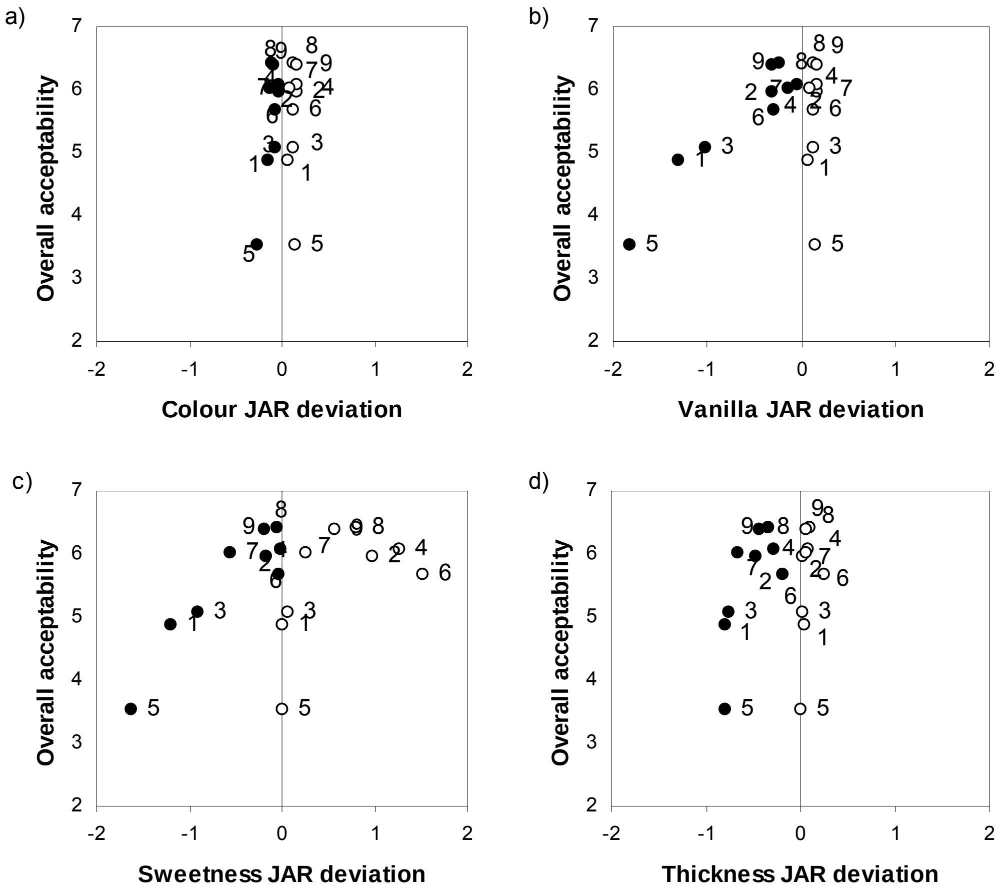


Figure 6. Relationship between overall acceptability data and JAR deviation for a) colour, b) vanilla flavour, c) sweetness and d) thickness of the formulations with CLR inulin. Identification of samples formulation in Table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16). Below JAR point deviations (●) and above JAR point deviations (○)

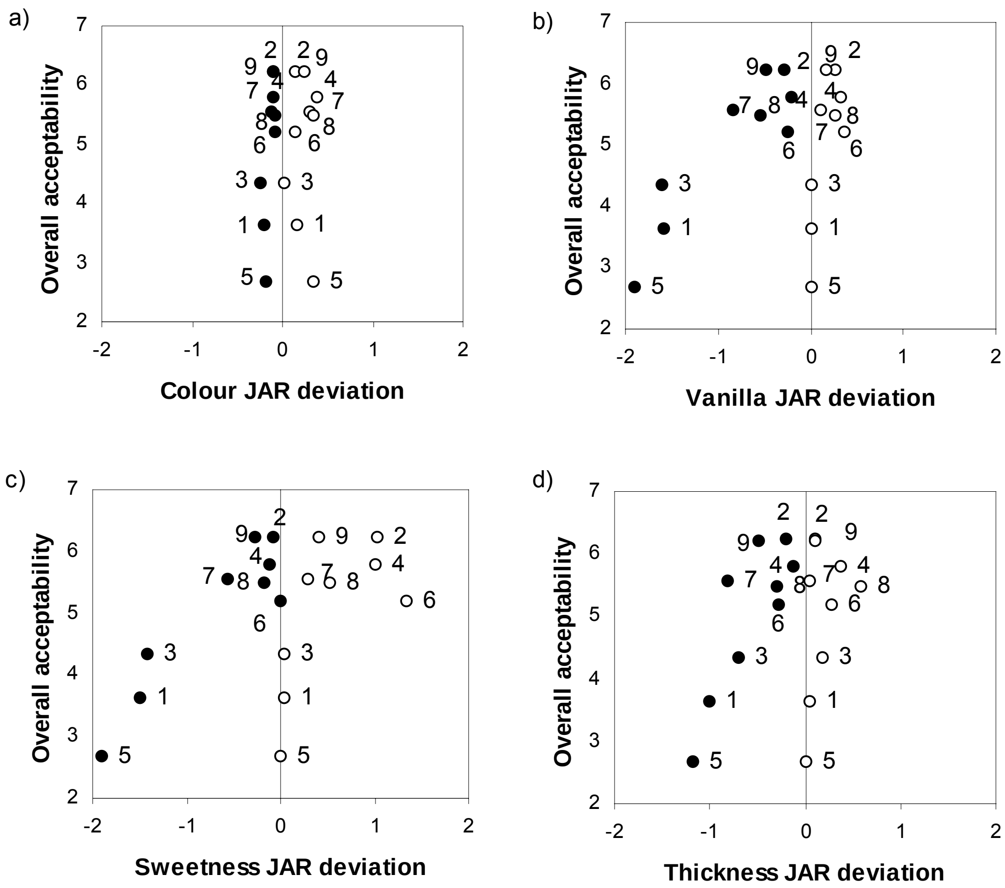


Figure 7. Relationship between overall acceptability data and JAR deviation for a) colour, b) vanilla flavour, c) sweetness and d) thickness of the formulations with TEX! inulin. Identification of samples formulation in table 1. Data of sample 9 is the average of data obtained for formulations corresponding to central point of the design (from 9 to 16). Below JAR point deviations (●) and above JAR point deviations (○).

3.2. Optimization of ingredient levels

In order to establish the relation between acceptability and concentration of both inulin and sucrose, data were fitted separately to a quadratic model (equation 1) for each type of inulin. ANOVA of the model was carried out in order to know the extent to which the model was able to predict the variability of the experimental data (Table 3).

Table 3. Analysis of variance of the regression models relating acceptability with sucrose (S) and inulin (I) concentrations.

Responses	Sources of variation	Df	Sum of squares	Mean square	*F*-ratio	*P*-value
Acceptability CLR[a]	Model	3	9.157	3.052	34.83	< 0.001
	Residual	12	1.052	0.088		
	Total	15	10.209			
Acceptability TEX![b]	Model	4	16.201	4.050	24.27	< 0.001
	Residual	11	1.813	0.165		
	Total	15	18.014			

[a] R^2 = 89.7. R^2 adjusted for df = 87.1. *P*- value (lack of fit) = 0.217.
[b] R^2 = 89.9. R^2 adjusted for df = 86.3. *P*- value (lack of fit) = 0.023.

For CLR inulin beverages, the regression model included both linear and quadratic terms for sucrose, and the linear term for inulin. Although this latter term was not significant (Table 4) it was included because it improved the model. The model without the linear term for inulin showed a significant lack of fit and when that term was included, lack of fit was not significant. This result indicated that inulin concentration can explain variations in acceptability data that are not explained only by the changes in sucrose concentration. A model was developed as follows:

$$\text{Acceptability} = 2.955 + 1.181S + 0.079I - 0.114S^2$$

$$(R^2 \text{ adjusted} = 87.1;\ P\text{-value (lack of fit)} = 0.217)$$

Table 4. Estimated regression coefficients of the fitted equations obtained for the two types of inulin, CLR and TEX!

Coefficient	Short chain inulin (CLR)				Long chain inulin (TEX!)			
	Estimate	Standard error	t-statistic	*P*	Estimate	Standard error	t-statistic	*P*
B_0	2.955	0.459	6.443	< 0.001	-1.577	1.652	-0.954	0.360
Linear								
B_1	1.181	0.121	9.702	< 0.001	1.561	0.169	9.211	< 0.001
B_2	0.079	0.068	1.151	0.272	1.387	0.020	2.444	0.033
Quadratic								
B_{11}	-0.114	0.014	-8.029	< 0.001	-0.148	0.568	-7.435	< 0.001
B_{22}					-0.126	0.051	-2.467	0.031

For sucrose, the linear coefficient was positive and the quadratic one negative, which indicated that acceptability increased with sucrose concentration up to a maximum value (around 5.5% sucrose) and higher amount of sucrose lowered acceptability. Linear coefficient of inulin was positive and thus acceptability increased with inulin concentration, although to a much lesser degree than with respective changes in sucrose concentration. The reduced equation was used to plot response surface that represented all combinations of the independent variables that had significant effects on the acceptability of the product (Fig. 8). This plot showed the maximum values of acceptability at concentrations of sucrose between 4 and 6.5 % (w/w) and at concentrations of inulin between 5 and 8%. A formulation with 4% sucrose and 7% inulin concentrations was selected to represent the optimum and to assure the bifidogenic effect of the beverage.

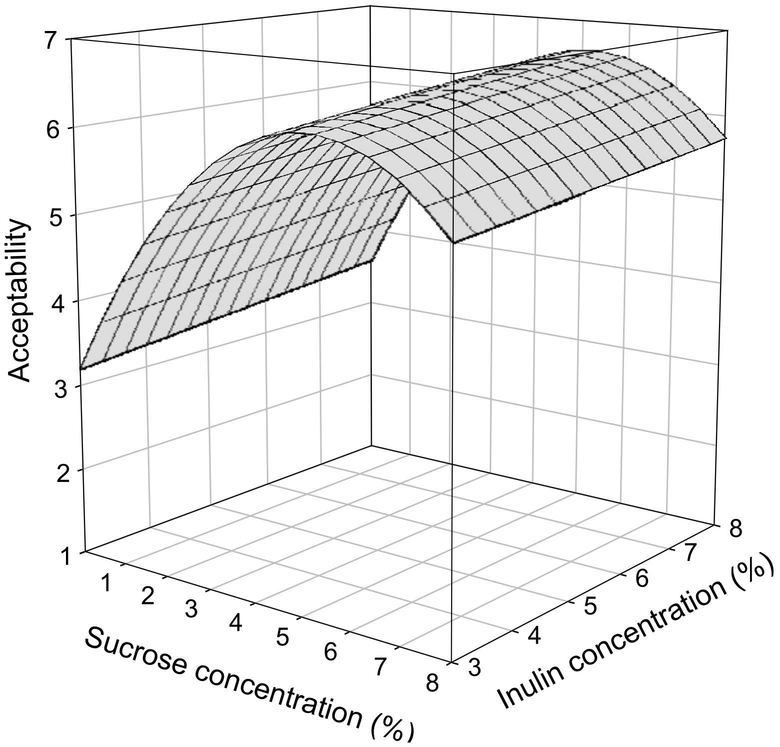


Figure 8. Response surface of acceptability of prebiotic low-fat milk beverages as related to sucrose and CLR inulin concentrations.

For TEX! inulin beverages, the regression model included linear and quadratic terms for both sucrose and inulin.

$$\text{Acceptability} = -1.577 + 1.561S - 0.148S^2 + 1.387I - 0.126I^2$$
$$(R^2 \text{ adjusted} = 86.3;\ P\text{-value (lack of fit)} = 0.023)$$

The model showed a significant lack of fit and alternative models were tried but no improvement was found. The lack of fit indicated that model does not fit enough the data. That means that the linear model has limited flexibility to characterize the relationship between acceptability and concentration of both inulin and sucrose. In this case it was observed that acceptability values for formulations with low sucrose concentration were not well predicted by the model. The linear coefficients for TEX! inulin were positive and of the same magnitude, indicating that an increase in concentration of both variables contributed to an increase in the acceptability of the beverage (Table 4). However, negative values were found for coefficient estimates of the quadratic terms, which indicated that when concentration of both ingredients increased around 6%, respectively, the acceptability decreased. Response surface obtained when plotting acceptability of samples against concentrations of both ingredients showed maximum values for both sucrose and inulin concentrations between 4 and 6.5 % (w/w) (Fig. 9). A centered point in this region, corresponding to 5.2 % (w/w) sucrose and 5.5 % (w/w) inulin was selected to represent the optimum formulation.

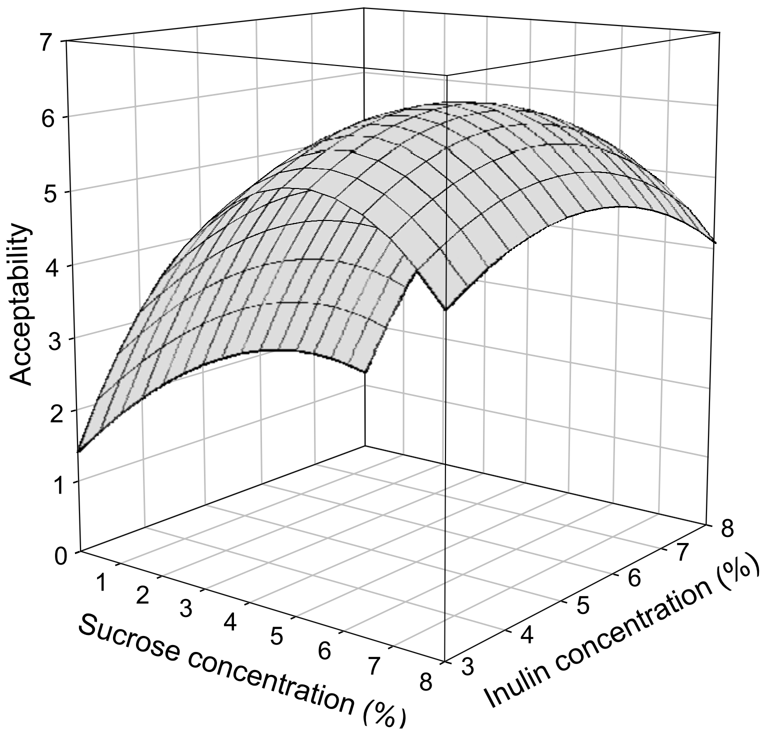


Figure 9. Response surface of acceptability of prebiotic low-fat milk beverages as related to sucrose and TEX! inulin concentrations.

In order to compare the acceptability of the two optimum low fat beverage formulations a preference paired comparison test was performed. No significant difference on acceptability between low-fat beverage with CLR inulin and that with TEX! inulin was found (Fig. 10). Finally, the two optimum low-fat beverages were compared with a full-fat control beverage. No differences were detected for any of the pairs. In spite of that, the tendency was that both inulin beverages were more acceptable than the control beverage.

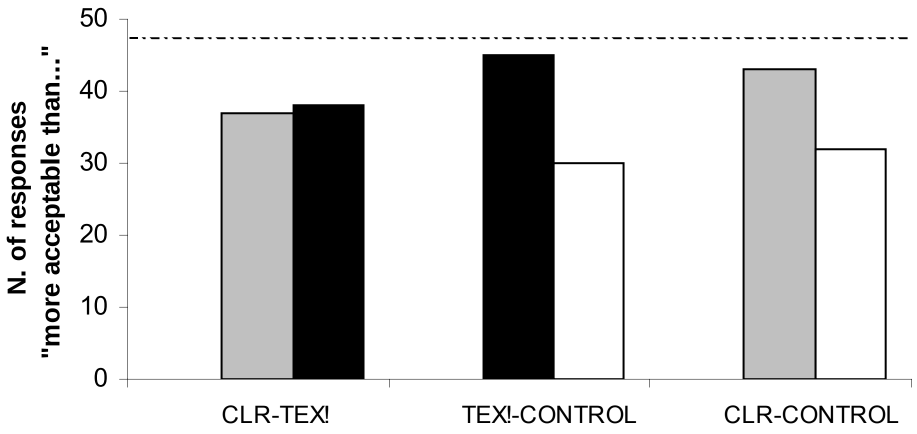


Figure 10. Paired comparison test between CLR (▭) and TEX! (■) optimum formulations and control (▭) sample. The dotted line indicates the minimum value of response for which the difference is significant (α = 0.05).

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RESUMEN Y DISCUSIÓN DE LOS RESULTADOS

1. Desarrollo y puesta a punto de una metodología para investigar la influencia de las opiniones, actitudes y expectativas de los consumidores en la aceptación de productos con características nutricionales especiales

En esta primera parte de la tesis se pretendía poner a punto una metodología que permitiera obtener información sobre la posible incidencia de las opiniones, actitudes y expectativas de los consumidores en la aceptación de productos funcionales o con características nutricionales especiales. Para llevar a cabo este estudio era necesario realizarlo en productos conocidos, habituales en el mercado y sobre los cuales los consumidores pudieran tener sus propias opiniones y actitudes. Teniendo en cuenta el segundo objetivo de esta tesis, se seleccionaron dos tipos de productos similares entre ellos, ambos con sabor a vainilla: batidos lácteos, sin ninguna connotación nutricional especial y bebidas de soja, cuyo consumo se asocia a beneficios en la salud cardiovascular, a la reducción del riesgo de padecer osteoporosis y cáncer de pecho y a la disminución de las alteraciones provocadas por la menopausia.

En primer lugar se analizaron las diferencias en color y en viscosidad, medidos instrumentalmente, entre tres batidos lácteos y tres bebidas de soja, ambos comerciales y de distintas marcas. Se determinaron las diferencias sensoriales perceptibles en los citados atributos y se analizó hasta qué punto las diferencias detectadas influían en la aceptabilidad de estos productos respecto a estos atributos. La consideración conjunta de los valores de los parámetros instrumentales, especialmente de L^*, a^* y b^*, permitió predecir razonablemente bien las diferencias perceptibles en el color de estos productos y explicar las diferencias en las preferencias de los consumidores respecto a este atributo. No ocurrió lo mismo con los valores de la viscosidad instrumental, que no se relacionaron bien con la viscosidad percibida sensorialmente ni con las diferencias en la aceptabilidad de estas bebidas por los consumidores respecto a este atributo. Ello confirmó que en la percepción de la viscosidad en la boca pueden influir otros factores, además de su resistencia a fluir y que para obtener productos de viscosidad sensorial similar no es suficiente la información reológica sino que es necesario evaluarlos sensorialmente.

A continuación, se realizó una experiencia en la que participaron un grupo de 142 consumidores, reclutados por una asociación de consumidores local (AVACU) y seleccionados de acuerdo con los siguientes criterios: género, edad y ser consumidores habituales de bebidas lácteas y/o vegetales. Cada consumidor evaluó la aceptabilidad de las muestras con una escala hedónica de nueve puntos en una cata ciega sin ninguna información sobre el tipo de producto que estaban evaluando. Un panel de 36 catadores previamente seleccionados y con experiencia en la evaluación de productos lácteos evaluó las diferencias en intensidad de color, de sabor a vainilla, de dulzor y de viscosidad. Primero se analizaron las diferencias en aceptabilidad entre las muestras; después se estudió si ésta aceptabilidad estaba influida por las características demográficas de la población encuestada, por sus hábitos de consumo o por sus preferencias individuales. Finalmente, se investigaron las posibles relaciones entre la aceptabilidad y las diferencias detectadas en la intensidad de los distintos atributos sensoriales evaluados. Los resultados obtenidos indicaron que existía una clara diferencia en la aceptabilidad de las muestras lácteas y las de soja. Cuando se consideró la información de todo el grupo de consumidores, las primeras fueron claramente más aceptables. No se detectaron diferencias significativas en la aceptabilidad de las distintas muestras entre el subgrupo de hombres y el de las mujeres. Sin embargo, el subgrupo de consumidores más joven consideró como más aceptable una de las muestras lácteas y como menos aceptables dos de las muestras de soja que el subgrupo de más edad. No se detectaron diferencias significativas en la aceptabilidad de las bebidas lácteas entre los consumidores habituales de leche de soja y los de batidos lácteos pero los primeros, encontraron las bebidas de soja significativamente más aceptables que los segundos. Después de analizar la relación entre la aceptabilidad de las muestras y la intensidad de los atributos sensoriales, se pudo concluir que para las muestras analizadas en este estudio las diferencias de aceptabilidad estaban más relacionadas con las diferencias percibidas sensorialmente que con las características de la población de consumidores encuestada. Esta conclusión no es extrapolable lógicamente a otros estudios de este tipo. En cada caso, la influencia de los distintos factores en la aceptabilidad dependerá de las características del alimento, de la magnitud de la diferencia sensorial perceptible entre las muestras y de las características de la población encuestada. Lo que sí se puede confirmar es que, en cualquier caso, si se analizan las opiniones de los distintos grupos de consumidores que forman la población encuestada, se puede obtener una información más completa sobre el grado de aceptabilidad real de un producto que si se considera exclusivamente el valor medio de aceptabilidad del grupo entero.

De cualquier forma, el método clásico de evaluar la aceptabilidad de los alimentos en el que el consumidor no tiene ninguna información sobre el producto que evalúa, no coincide en absoluto con su situación en el mundo real, en el que la marca, el precio o las características nutricionales del producto pueden modificar la respuesta del consumidor tanto en lo referente a su aceptación como a la intención de comprarlo. Por ello se analizó la influencia del tipo de información nutricional que recibe el consumidor sobre un determinado producto (fotografía del envase real ó un extracto de la información nutricional en una ficha) y de algunas actitudes del consumidor (interés o no por comer saludablemente o fobia o filia a los alimentos nuevos) en la aceptabilidad y en la intención de compra de las mismas muestras de batidos lácteos y de bebidas de soja. Los resultados obtenidos confirmaron, por un lado, que las características del envase pueden influir en la opinión de los consumidores sobre la posible aceptabilidad del producto y en la intención de compra. Un envase mal diseñado o poco atractivo hace pensar al consumidor que el producto es poco aceptable y disminuye su interés en adquirirlo. Por el contrario, un envase con un buen diseño, sugiere que el producto que contiene es de buena calidad e incrementa el interés por adquirirlo. Cuando el consumidor además de ver el envase probó el producto, la influencia del envase en la aceptación y en la intención de compra, disminuyó claramente. Por otro lado, se ha puesto de manifiesto que el interés por comer saludablemente puede aumentar la intención de compra e incluso, incrementar la aceptabilidad de determinados tipos de productos con características nutricionales específicas, como las bebidas de soja. Al intentar modelizar la respuesta de los consumidores a las expectativas generadas por los dos tipos de información, se observó que, en conjunto, el comportamiento se ajustaba al modelo de asimilación. Sin embargo, el análisis de las respuestas individuales indicó distintas tendencias en función del tipo de bebida y del tipo de información. El porcentaje de consumidores cuya respuesta se ajustó al modelo de asimilación fue superior en las muestras de bebidas de soja (55-67%) que en las lácteas (31-64%), independientemente del tipo de información suministrada. En las bebidas lácteas, este porcentaje fue superior cuando la información se suministró en la ficha y en las de soja, cuando se suministró el envase. En conjunto, el porcentaje de consumidores a los que no les influyó la información o cuya respuesta no siguió un modelo claro, fue superior en las bebidas lácteas (32-57%) que en las de soja (16-36%). Ello permite concluir que la influencia de las expectativas generadas por la información en la aceptación de un producto, no sólo depende del tipo de información que reciba el consumidor, sino también, de las características nutricionales o sensoriales de cada producto. La metodología puesta a punto en este trabajo, en combinación con el análisis de las características sensoriales de un producto, puede resultar de gran utilidad para predecir la respuesta real de los consumidores a los productos con características nutricionales especiales.

2. Desarrollo y optimización de la aceptabilidad de nuevas bebidas lácteas, bajas en grasa y con características prebióticas

No hay una forma simple y rápida para asegurar el éxito de un producto en el mercado, entendiendo como tal el que se manifiesta en un proceso de compra y de consumición continuado por un sector específico de la población. Se ha comentado anteriormente, y puesto de manifiesto en la primera parte de esta tesis, que dicho éxito no sólo depende de las características y de la calidad sensorial del alimento. Pero este hecho no disminuye la necesidad de reducir al mínimo los riesgos de fracaso de un producto en el mercado originados por deficiencias en su calidad sensorial. Uno de los métodos mas utilizados para optimizar la aceptabilidad de productos formulados es el de la superficie de respuesta. Su correcta aplicación requiere la identificación previa de un número discreto de factores y lleva implícito el desarrollo de un modelo matemático que refleje la relación entre estos factores o variables independientes y la aceptabilidad o variable dependiente. En este tipo de estudios, la primera cuestión es la elección de los ingredientes que se van a modificar en la formulación y el establecimiento del intervalo de variación de los mismos.

En primer lugar se analizó el efecto de la adición de diferentes tipos de inulina (oligofructosa, nativa y de cadena larga) a distintas concentraciones (2, 4, 6, 8 y 10%, p/p) en el comportamiento de flujo de sistemas modelo de bebidas lácteas. El flujo de las muestras, tanto las elaboradas con leche entera como las elaboradas con leche desnatada se ajustó bien al modelo de Newton excepto las muestras con leche entera y con las concentraciones mayores de inulina de cadena larga (8 y 10%) que mostraron un flujo pseudoplástico que se ajusto bien al modelo de Ostwald- de Waele. No se detectaron diferencias significativas entre la viscosidad de las muestras elaboradas con leche entera y las elaboradas con leche desnatada y distintas concentraciones de cada tipo de inulina: 4-10% de oligofructosa; 6-8% de inulina nativa y 4-6% de inulina de cadena larga. Cuando en la formulación de las muestras analizadas se incluyó una pequeña cantidad de kappa-carragenato (0.02%, p/p), ninguna de las inulinas adicionadas a ninguna de las concentraciones ensayadas fue capaz de compensar el efecto de la eliminación de la grasa en la viscosidad de los sistemas modelo de bebidas elaborados con leche desnatada.

A continuación, se estudió si las diferencias detectadas en el comportamiento de flujo de los sistemas modelo de bebidas lácteas daban lugar a diferencias perceptibles en la viscosidad y en la cremosidad de las mismas. Primero, se analizó el efecto de la adición de los tres tipos de inulina a una concentración del 6%, elegida porque se consideró que dicha concentración tenía un efecto prebiótico, en los dos atributos sensoriales. Después, se exploró, hasta qué punto, los diferentes tipos de inulina podrían utilizarse como sustitutos de grasa analizando las diferencias percibidas en viscosidad y en cremosidad entre las muestras elaboradas con leche entera y las muestras elaboradas con leche desnatada y con diferentes concentraciones de los tres tipos de inulina añadidas. La adición de cualquiera de los tipos de inulina a cualquiera de los tipos de leche provocó un incremento significativo tanto de la viscosidad sensorial como de la cremosidad. Sin embargo, dicho incremento en la viscosidad sensorial y en la cremosidad de las muestras fue diferente en función del tipo de leche y de inulina utilizados. Para la viscosidad se observó que la muestra con inulina nativa, independientemente del tipo de leche se percibió como más viscosa, aunque sin diferencias significativas con la muestra con leche desnatada e inulina de cadena corta y la muestra con leche entera e inulina de cadena larga. La muestra de inulina de cadena corta se percibió como menos viscosa, aunque en el caso de la leche desnatada no se detectaron diferencias significativas con la muestra de inulina de cadena larga. En cuanto a la percepción de la cremosidad de la serie de muestras con leche desnatada, se observó que la muestra con inulina de cadena larga fue la menos cremosa y más parecida a la muestra sin inulina, mientras que las muestras con inulina de cadena corta y nativa fueron percibidas como más cremosas sin diferencias entre ellas. En la serie con leche entera no existieron diferencias en la cremosidad de las muestras con inulina y se percibieron siempre más cremosas que la muestra sin inulina. En resumen, se pudo concluir que los resultados del análisis de la viscosidad de las muestras tanto instrumental como sensorial, indicaron que tanto el aumento de la concentración como el tipo de inulina incrementaban la viscosidad de las muestras y que el aumento fue especialmente notable para la muestra con inulina de cadena larga al 10%. En cuanto a la sensación de cremosidad, de nuevo los factores de concentración y tipo de inulina influyeron en el incremento de la percepción de este atributo, siendo especialmente notable a la máxima concentración, en que las muestras fueron percibidas igual de cremosas que la muestra de leche entera menos la muestra de inulina de cadena larga que fue percibida como la más cremosa.

De acuerdo con la información obtenida en los estudios anteriores, se diseñó una serie de experiencias para optimizar la aceptabilidad de dos nuevas formulaciones de batidos lácteos con sabor a vainilla, elaboradas con leche desnatada y con carácter prebiótico cada una de ellas con una inulina de distinto tamaño molecular: oligofructosa o inulina de cadena corta e inulina de cadena larga. Se utilizó el método de la superficie de respuesta. Para cada tipo de inulina, se fabricaron 16 formulaciones con leche desnatada variando la concentración de inulina (3-8%) y la de sacarosa (0-8%) y manteniendo fijos el resto de los ingredientes. Las superficies de respuesta obtenidas indicaron que las muestras con concentraciones entre 5 y 8% de inulina de corta y de sacarosa entre 4 y 6.5%, estaban localizadas en la región de aceptabilidad máxima. Cuando la inulina añadida fue la de cadena larga, las muestras de aceptabilidad máxima estaban definidas por concentraciones de inulina y de sacarosa que oscilaron entre 4 y 6.5%. Se seleccionaron dos formulaciones dentro de las zonas de aceptabilidad máxima como representativas de los productos optimizados: Para las muestras con inulina de cadena corta, la formulación con el 4% de sacarosa y 7% de inulina y para las muestras con inulina de cadena larga, la formulación con 5.2% de sacarosa y 5.5% de inulina. Se analizó si había diferencia en la preferencia de las dos muestras elaboradas con las dos formulaciones seleccionadas y no se detectó diferencia significativa. Finalmente, se comparó el grado de preferencia de cada una de ellas respecto al de una muestra control, elaborada con leche entera, con los mismos ingredientes pero sin inulina añadida. Se observó una tendencia hacia una mayor preferencia de las muestras correspondientes a las formulaciones optimizadas frente a la muestra control, aunque en ninguno de los dos casos la diferencia llegó a ser significativa. Estos resultados confirman, que además de sus especiales características nutricionales, como fuente de fibra e ingrediente de carácter prebiótico, la inulina puede utilizarse como sustituto de grasa en la formulación de bebidas lácteas sin que éstas disminuyan su aceptabilidad respecto a las elaboradas con leche entera, siempre que la formulación se ajuste en función del tamaño molecular de la inulina añadida.

CONCLUSIONES

1. Existen diferencias instrumentales en el color y en la viscosidad entre las bebidas comerciales lácteas y de soja. Los valores de los parámetros instrumentales de color permitieron predecir razonablemente bien las diferencias perceptibles en el color de estos productos y explicar las diferencias en las preferencias de los consumidores respecto a este atributo. Los valores de la viscosidad instrumental no se relacionaron bien con la viscosidad percibida sensorialmente ni con las diferencias en la aceptabilidad de las bebidas respecto a este atributo.

2. En los estudios sobre la aceptabilidad de los alimentos, el análisis de las respuestas de los distintos subgrupos de consumidores que configuran la población encuestada, tanto los formados en función de sus características demográficas, de sus hábitos alimentarios o según sus preferencias individuales, permite obtener una información más real sobre la aceptabilidad de un producto que si se considera exclusivamente el valor medio de aceptabilidad del grupo completo de consumidores encuestados.

3. La metodología puesta a punto en este trabajo para evaluar la incidencia que la información nutricional tiene en la aceptabilidad y en la intención de compra de diferentes productos, puede aportar información de interés. En cada caso concreto, la consideración conjunta de esta información y de la que se obtenga al analizar la calidad sensorial de cada alimento con características nutricionales especiales, puede ser útil para predecir la respuesta de los consumidores en el mercado.

4. La adición de inulinas con diferente tamaño molecular influye en el comportamiento de flujo y en la viscosidad y cremosidad percibidas en las bebidas lácteas. El efecto depende también de la concentración de inulina añadida y del contenido en grasa de la leche utilizada para elaborarlas. La información obtenida en esta tesis abre perspectivas para la formulación de nuevos productos con características nutricionales concretas (efecto fibra o efecto prebiótico, bajos en grasa, con contenido en azúcares reducido, etc) y aceptables para el consumidor.

5. Se ha desarrollado y optimizado la aceptabilidad de dos formulaciones de nuevas bebidas lácteas, bajas en grasa y con características prebióticas. Aunque de distinta composición, ambas resultaron igual de preferidas por los consumidores y no se detectaron diferencias significativas entre la preferencia por cada una de ellas y la de una muestra control de la misma composición básica, pero elaborada con leche entera y sin inulina añadida.