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Characteristics of prebiotic food products containing inulin

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Abstract

Purpose – The purpose of this paper is to identify food products being developed with the addition of the prebiotic inulin (a soluble, fermentable dietary fibre that stimulates the growth of beneficial bacteria in the colon), in order to determine how its addition modifies their probiotic, physicochemical and sensory characteristics.

Design/methodology/approach – The paper's approach is a systematic review of the Web of Science, Medline/Pubmed and Scielo-Br electronic databases, from 2001 to 2011. Of the 256 abstracts initially retrieved, those reporting development of products containing inulin were included, while those regarding literature review, clinical investigations, inulin extraction and effects on the human body were excluded. Full papers of all the 28 studies identified as relevant to the aims of the review were then obtained.

Findings – Inulin quantities added to products varied from 1 to 32 per cent. Products containing inulin had improved microorganism counts and received either equal or better scores in sensory analysis tests. pH and colour of high fat content products were not significantly altered by inulin addition. Texture profile of high protein and carbohydrate content products was irregularly altered by inulin addition. Food composition was found to determine the necessary amount of inulin to induce the desired changes. Highest added quantities were observed in the group of products with high carbohydrate content.

Originality/value – The paper presents a compilation of information regarding inulin percentage needed to alter physicochemical and sensory characteristics of products with different protein, fat and carbohydrate content.

Keywords Inulin, Food products, Sugar, Natural fibres, Prebiotics

Paper type Literature review

The relationship between high consumption of certain foods and low risk of cardiopathies and selected types of cancer (colon, breast and prostate) calls the attention for the importance of diet as the main factor contributing to a healthy lifestyle (Dixey *et al.*, 2001; Niva, 2007; Chen, 2011; Krutulyte *et al.*, 2010).

Diet plays such a role not only because of the nutritional value of foods, but also because foods contain natural compounds with functional properties (i.e. which benefit one or more targeted functions in the body), increasing health and well-being due to their potential in reducing the risk of diseases (Roberfroid, 2002; Spence, 2006; Alzamora *et al.*, 2005; Devcich *et al.*, 2007).

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Nevertheless, consumers tend to seek foods that are not only healthy and nutritious, but also flavourful. The growing demand on the part of consumers for foods that offer, besides high sensory and nutritional quality, benefits associated with health, have driven a need for the development of new products to meet the demands of the market (Verbeke, 2006; Urala and Lähteenmaki, 2007; Landström *et al.*, 2009). A series of new products enriched with physiologically active components, such as prebiotics, have become one of the priorities of research in the food industry (Bech-Larsen and Scholderer, 2007; Reid, 2008; Buriti *et al.*, 2010a).

Prebiotics are defined as non-digestible food ingredients that selectively stimulate the multiplication and/or activity of one or more species of bacteria in the colon, and thereby bring benefits to those who ingest them. When added to food products, prebiotics modulate the composition of the intestinal microbiota (Roberfroid, 2002; Fuller and Gibson, 2005; Saad, 2006; Leiß *et al.*, 2008; Wang, 2009; Roberfroid *et al.*, 2010).

Prominent among prebiotics is inulin, a carbohydrate consisting of fructose subunits (2 to 150), linked to each other and to a terminal glucose. Inulin is a soluble and fermentable dietary fibre that is not digested by the enzymes of the human digestive tract and for this reason does not contribute calories to the diet. Inulin stimulates the growth of beneficial bacteria in the colon, and these, in turn, suppress the activity of undesirable bacteria (Kolida and Gibson, 2002; Roberfroid, 2007; Juskiewicz *et al.*, 2008; Ramirez-Farias *et al.*, 2009).

Inulin has also been studied for other possible effects beneficial to health, such as increasing bone absorption of calcium (Dahl *et al.*, 2005; Weaver, 2005; Lobo *et al.*, 2009), raising resistance to gastrointestinal infections (Dahl *et al.*, 2005; Sauer *et al.*, 2007; Wendy *et al.*, 2008), and helping prevent arterial hypertension (Rault-Nania *et al.*, 2008) and cancer of the colon (Gibson *et al.*, 2005; Pool-Zobel and Sauer, 2007; Davis and Milner, 2009).

Besides its health benefits, inulin can be used as a fat substitute, in order to lower energy content while improving sensory aspects of modified products (Tárrega and Costell, 2006; Guggisberg *et al.*, 2009; Buriti, 2010b, Peressini and Sensidoni, 2009; Poinot *et al.*, 2010; Sun-Waterhouse *et al.*, 2010).

The aim of this review was, therefore, to identify which food products are being developed with inulin, in order to determine how inulin addition modifies their prebiotic, physicochemical and sensory characteristics.

Method

We systematically searched Web of Science, Medline/Pubmed and Scielo-Br databases for literature from 2001 to June 2011 using the following search terms: "inulin" and "product". First search retrieved 256 articles; 168 articles from Web of Science, 79 articles from Medline/Pubmed and nine articles from the Scielo-Br database. Inclusion criteria were defined as: report on the development of products containing inulin; in English, Spanish or Portuguese. Papers were excluded if they presented literature review, if described solely clinical investigations, if concerned with the extraction of inulin and those that merely reported on the effects of inulin on the human body. Abstracts were reviewed to identify those relevant to the aims of the review, for which the full papers were then obtained. The ones that were only partially available were obtained from the authors themselves, through e-mailed requests. In this way, 28 studies fulfilled the inclusion criteria for this review. Due to the range of largely

different methodologies employed, it was not possible to apply a single quality assessment method to studies.

Results and discussion

Number of selected papers according to year, country of publication and authorship are presented in Table I. Brazil and Spain were the main countries of publication. From

Year of publication	Country of origin	Author(s)
2001	Spain	Mendoza, E., García, M.L., Casas, C. and Selgas, M.D.
2004	United Kingdom	Brennan, C.S., Kuri, V. and Tudorica, C.M.
	Brazil	Moscatto, J.A., Prudêncio-Ferreira, S.H. and Hauly, M.C.O.
2005	Brazil	Fuchs, R.H.B., Borsato, D., Bona, E. and Hauly, M.C.O.
	Canada	Gokavi, S., Zhang, L., Huang, M., Zhao, X. and Guo, M.
	Brazil	Hauly, M.C.O., Fuchs, R.H.B. and Prudêncio-Ferreira, S.H.
2006	Brazil	Dutcosky, SD., Grossmann M.V.E., Silva, R.S.S.F. and Welsh, A.K.
	Spain	Garcia, M.L., Cáceres, E. and Selgas, M.D.
2007	Brazil	Aragon-Alegro, L.C., Alegro, J.H.A., Cardarelli, H.R., Chiu, C. and Saad, S.M.I.
	USA	Aryana, K.J., Plauche, S., McGrew, P. and Shah, N.P.
	Brazil	Gomes, C.R., Vissotto, F.Z., Fadini, A.L., Faria, E.V. and Luiz, A.M.
	Germany	Hempel, S., Jacob, A. and Rohm, H.
	Germany	Nowak, B., von Mueffling, T., Grotheer, J., Klein, G. and Watkinson, B.M.
2008	United Kingdom/New Zealand	Brennan, C.S. and Tudorica, C.M.
	United Kingdom/New Zealand	Brennan, M.A., Monro, J.A. and Brennan, C.S.
	Brazil	Buriti, F.C.A., Cardarelli, H.R. and Saad, S.M.I.
	Brazil	Cardarelli, H.R., Buriti, F.C.A., Castro, I.A. and Saad, S.M.I.
	Brazil	Silveira, K.C., Brasil, J.A., Livera, A.V.S., Salgado, S.M., Faro, Z.P. and Guerra, N.B.
2009	Brazil	Alves, A.L., Richards, N.S.P.S, Becker, L.V., Andrade, D.F., Milani, L.I., Rezer, A.P.S. and Scipioni, G.C.
	Brazil	Capriles, V.D., Soares, R.A.M., Pinto e Silva, M.E.M. and Áreas, J.A.G.
	Brazil	Lobato, L.P., Grossmann, M.V.E. and Benassi, M.T.
2010	Spain	Arcia, P.L., Costell, E. and Tárrega, A.
	Brazil	Buriti, F.C.A., Castro, I.A. and Saad, S.M.I.
	Brazil	Debon, J., Prudêncio, S.E. and Petrus, J.C.C.
	Brazil	Pinto, A.L.D. and Paiva, C.L.
	Germany	Zahn, S., Pepke, F. and Rohm, H.
2011	Spain	Alvarez, M. D., Fernández, C., Solas, M.T. and Canet, W.
	Spain	Beriain, M.J., Gómez, I., Petri, E., Insausti, K. and Sarriés, M.V.

Table I.
Selected papers (28) according to year, country of publication and authorship

2007 on, the number of published papers increased considerably. Papers do not present any reason for studying effects of inulin addition to any given products and do not state if food products are largely consumed in their country of origin or not.

The 28 selected studies were divided in four groups (Tables II-V, papers organised in alphabetical order according to the initial of the first author).

The first group (six papers, Table II) comprises works with the sole objective of giving prebiotic characteristics to the developed products (chocolate mousse, yogurt, *petit-suisse* cheese, fermented milk, fermented soy beverage and fermented oat beverage). Prebiotic characteristics were considered present, by authors of all the six papers, when the number of probiotic microorganisms, especially *lactobacilli,* increased in the studied products. Each study reported adding different quantities of inulin to products (from 0.2 to 5 per cent), therefore it is not possible to conclude that adding a specific quantity of inulin to a food product will turn it into a prebiotic food.

Regarding pH, five among the six papers reported no significant differences in the samples containing inulin when compared to the control samples. *Petit-suisse* cheese was the only product where pH values were different between inulin and control samples, but since honey and fructooligosaccharides were also added, it was not possible to determine that such effect was due solely to inulin addition.

Three papers evaluated viscosity, in one no differences were observed between the samples with and without inulin (yogurt), and in the other two (fermented milk and fermented oat beverage) viscosity improved with inulin addition.

Even focusing in the microbial growth to prove prebiotic potential, four of the six papers did sensory tests with inulin-added products. Two did not find differences, and two verified that inulin addition improved sensory attributes such as flavour and appearance (fermented oat beverage) and improved global acceptance of the product (*petit-suisse* cheese). The product with higher global acceptance scores was the one with the highest percentage of added inulin (10 per cent);

No paper in this first group of products (Table II), evaluated *in vivo* the effect of the ingestion of the product containing inulin in order to characterise them as prebiotic, as would be ideal. Classification of the developed products as prebiotic was done based on microorganism counts, and inulin addition indeed contributed for their increase in the modified products.

The remaining studies (22 papers, Tables III-V) dealt on the development of products with the objective of improving their physicochemical qualities, and/or their sensory properties. Studies were subdivided according to type of product. Table III comprises five studies regarding products of high protein content (dairy and fermented beverages); Table IV comprises four studies with products of high fat content (sausages), and Table V comprises 13 studies with products of high carbohydrate content (dough, pasta, sweets and desserts).

When developing a yogurt based in any other ingredient than milk, certain characteristics of the original product must be maintained, such as pH, viscosity, acidity, protein and lipid content. Fuchs *et al.* (2005) and Hauly *et al.* (2005) developed soya-based fermented beverages, which they called "yogurt", with inulin. In both products, pH was considered satisfactory after the addition of inulin, and protein/lipid content were maintained. Only in the product developed by Hauly *et al.* (2005) was verified that viscosity, cohesiveness and adhesiveness increased after the addition of 4.43 per cent of inulin and 14.23 per cent of oligofructose.

Product/author/year	Study's main features	Relevant results
Chocolate mousse Aragon-Alegro *et al.* (2007)	Physicochemical, microbiological and sensory analysis of potentially symbiotic chocolate mousse	No significant differences were observed between control sample (without probiotic or prebiotic addition) and other samples: probiotic (containing the probiotic microorganism *Lactobacillus paracasei* subsp. *paracasei* LBC 82) and symbiotic sample (with *Lactobacillus paracasei* subsp. *paracasei* LBC 82 and inulin (5.01 per cent))
Yogurt Aryana *et al.* (2007)	Viscosity, syneresis, pH, colour, sensory analysis and *lactobacillus* counts were performed in three samples of fat-free plain yogurt manufactured with inulin of various chain lengths and *Lactobacillus acidophilus*, each one containing 1.5 per cent of prebiotic of different chain sizes (*oligofructose P95 – average degree of polymerization 4, inulin GR – average degree of polymerization 10, inulin HP – average degree of polymerization 23*) and prebiotic *L. delbrueckii* ssp. *Bulgaris* (0.05 percent) and compared with control sample containing only prebiotic *L. delbrueckii* ssp. *Bulgaris* (0.05 percent)	No significant difference was observed in viscosity between control sample and other samples. PH was significantly higher in the P95 sample ($p < 0.05$) when compared with the control and other samples. Storage time increased syneresis values significantly in the samples containing prebiotic. Prebiotic samples had significantly higher counts of *L. acidophilus* than control samples. No significant differences among sample colours were observed between L^*, a^* or b^*. Flavour scores of all yogurts were ≥ 7 on a scale of 1 to 10. Control and P95 yogurts received scores of mostly 8 and few 9, while yogurts with HP and GR received an almost equal distribution of 7 and 8
Petit-suisse cheese Cardarelli *et al.* (2008)	Addition of three different types of prebiotic (inulin BeneoTM ST, Orafti, Oreye, Belgium); oligofructose (BeneoTM P95, Orafti) and oligosaccharides from honey (eucalyptus honey, Biosciences Institute-University of São Paulo, São Paulo, Brazil) to samples of *petit-suisse* cheese containing *L. acidophilus* and *B. animalis* subsp. *Lactis.*	PH values decreased significantly during storage in all samples ($p < 0.05$). *L. acidophilus* and *B. animalis* subsp. *Lactis* counts reduced during storage ($p < 0.05$). Significant differences in sensory analysis ($p < 0.05$) were only observed after 28 days of storage (lower scores for control product and higher scores for the product containing inulin). Flavour was the preferred attribute, except for the control product

(*continued*)

Table II.
Studies reporting the development of products containing inulin with the main objective of making them prebiotic

Table II.

Product/author/year	Study's main features	Relevant results
Fermented milk Debon *et al.* (2010)	Rheological and physicochemical characterization of prebiotic micro filtered fermented milk. Samples of fermented milk with *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* (control) were compared with fermented milk containing *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus salivarius* ssp. *thermophilus* with inulin (5 per cent)	Addition of inulin resulted in an increase ($p < 0.05$) of total solids content. No differences were observed between the pH values ($p > 0.05$) of the fermented milk (control and prebiotic). Storage time influenced viscosity – in the control sample the difference was significant after 7 days, while in the prebiotic sample the difference was observed after 14 days ($p < 0.05$)
Fermented beverage Gokavi *et al.* (2005)	Samples of oat-based symbiotic beverage fermented by *Lactobacillus plantarum, Lactobacillus paracasei ssp. Casei,* and *Lactobacillus acidophilus* were compared with samples containing the same probiotic microorganisms plus 0.2 per cent inulin	Sensory analysis results indicated the symbiotic sample obtained higher scores in appearance, flavour, acidity, sourness, saltiness, viscosity and preference ($p < 0.05$)
Pumpkin flake-based drink Silveira *et al.* (2008)	Prebiotic characteristics and acceptability of a pumpkin flake-based drink containing inulin (0.5 and 1.0 per cent)	Formulations containing different concentrations of inulin presented higher bacterial counts than control formulation. Formulation containing higher percentage of inulin presented higher moisture and fibre content. No p values were given for such analyses. As to product acceptance, formulations did not differ significantly ($p > 0.05$)

Table III.
Studies on the development of products of high protein content with the objective of improving their physicochemical qualities, and/or their sensory properties

Product/author/year	Study's main features	Relevant results
Frozen yogurt Alves *et al.* (2009)	Sensorial acceptance and characterization of goat's milk frozen yogurt with addition of prebiotics *Bifidobacterium* Bb-12 and *Lactobacillus acidophilus* LA-5 (Bio-Rich®), as well as 1 per cent inulin	Inulin influenced texture characteristics, improving creaminess, airiness and viscosity. No p values were reported
Yogurt Brennan and Tudorica (2008)	Rheological, textural and sensory quality of whole-milk yogurt, skimmed-milk yogurt, skimmed-milk yogurt with beta-glucan (0.5, 1.0, 1.5, 2.0 and 2.5 per cent), skimmed-milk yogurt with inulin (2.0, 4.0 and 6.0 per cent) and skimmed-milk yogurt with partially hydrolysed guar gum (2.0, 4.0 and 6.0 per cent)	Whole-milk yogurt had lower syneresis when compared with skimmed-milk yogurt ($p < 0.05$). Yogurt containing inulin had higher viscosity than whole-milk yogurt ($p < 0.05$). Inulin increased product firmness and consistency when compared with skimmed-milk yogurt and whole-milk yogurt. Samples containing inulin had lower viscosity ($p < 0.05$) than those with partially hydrolysed guar gum. Yogurt samples containing inulin received higher scores in sensory analyses, but differences were not significant ($p > 0.05$)
Fresh cream cheese Buriti *et al.* (2008)	Fat content, texture profile and sensory analysis of fresh cream cheese samples containing *Lactobacillus paracasei, Lactobacillus paracasei* and inulin (1, 5 and 10 per cent), and control	In the sensory analysis the prebiotic product obtained lower preference scores and the symbiotic had the higher scores, but they did not differ significantly in relation to the control ($p > 0.05$). Acidity was mentioned as motive for lower preference, while flavour and texture (creaminess, spreadability, and consistency) were the motives for higher preference
Soy "yogurt" Fuchs *et al.* (2005)	Physicochemical analyses of soy "yogurt" containing 0.5, 2.5, and 4.5 per cent) inulin	Samples did not differ in pH or acidity. Main variable in yogurt preparation was duration of fermentation; carbohydrate content of all samples of soy yogurt containing inulin was high
Soy "yogurt" Hauly *et al.* (2005)	pH, physicochemical and rheological properties, texture profile, and sensory analyses of soy "yogurt" without prebiotic addition and soy "yogurt" containing inulin (4.43 per cent) and oligofructose (14.24 per cent)	Supplemented soymilk yogurt presented higher carbohydrate content, pH and acidity when compared with cow milk yogurt. Lipid and protein content did not differ, while calcium and sodium content were lower in the soymilk yogurt. Iron content was higher in the soymilk yogurt. Viscosity, cohesiveness and adhesiveness were higher in the prebiotic yogurt, while hardness was lower

Table IV.
Studies on the development of products of high fat content with the objective of improving their physicochemical qualities, and/or their sensory properties

Product/author/year	Study's main features	Relevant results
Chorizo Beriain *et al.* (2011)	Proximate analysis, pH, processing loss, water activity, lactic acid bacteria, physicochemical composition, instrumental colour, texture profile and sensory evaluation of low-salt, inulin (3, 6 and 10 per cent) and olive-oil enriched Pamplona-style chorizo	Addition of olive oil alginate emulsion and 6 per cent inulin resulted in a low-salt, reduced-fat product (20 per cent less fat than traditional chorizo), richer in monounsaturated fatty acids (10 per cent). Product retained sensory notes similar to those of the traditional chorizo and had good acceptability rating
Mortadella Garcia *et al.* (2006)	Effect of inulin on the textural and sensory properties of *mortadella* (Spanish cooked meat product). Control product was compared with low-fat ones, containing 2.5, 5.0 and 7.5 per cent of powdered inulin or 4.5, 9.1 and 13.6 per cent of gel inulin	Fat and energy content decreased in the low-fat inulin-enriched product. Adhesiveness and hardness were higher in the samples with powdered inulin, and lower in the samples with gel inulin when compared to control. Cohesiveness was significantly different between control sample and samples with powdered inulin
Fermented sausages Mendoza *et al.* (2001)	Physicochemical, microbiological, sensory analysis and texture profile of low-fat, medium and high-fat sausages containing different percentages of inulin (7.5 per cent and 12.5 per cent)	Addition of inulin gave the sausages softer texture but had little effect on juiciness
Bologna-type sausages Nowak *et al.* (2007)	Energy content, sensory properties, storage time, microbiological shelf life, physicochemical analyses, texture profile, colour, residual gases and sensory analysis of German Bologna-type sausages formulated with 3, 6, 9 and 12 per cent inulin and 0.3 per cent phosphate or 0.3 per cent citrate	Statistically significant results ($p < 0.05$): samples containing inulin presented significant reduction in fat content (up to 64.8 per cent). Energy content reduced from 261 Kcal/100 g (control) to 137 Kcal/100 g (12 per cent inulin). In instrumental analysis fracturability was lower for the samples with inulin and phosphate. Hardness was significantly increased after 23-day storage in all samples with inulin when compared with control. Adhesiveness was higher in all samples with inulin when compared to control; gumminess increased with increased quantities of inulin. Colour was significantly lighter in the samples containing inulin and citrate than in the samples containing inulin and phosphate

Table V.
Studies on the development of products of high carbohydrate content with the objective of improving their physicochemical qualities, and/or their sensory properties

Product/author/year	Study's main features	Relevant results
Mashed potatoes Alvarez *et al.* (2011)	Effect of the addition of inulin (0, 1.5, 3, 4.5 and 6 percent) on viscoelastic properties and microstructure of fresh and frozen/thawed mashed potatoes (FMP and F/TMP) formulated without and with added cryoprotectants (kappa-carrageenan (j-C) and xanthan gum (XG) was investigated	Results showed that inulin concentration was the factor that set the minor difference among most of rheological properties, firmness and overall acceptability (OA) of the samples. Inulin effect on the thickening of the product was limited, which is mainly ascribed to a high heating temperature reached by the product during manufacture process inducing inulin hydrolysis
Dairy dessert (I) Arcia *et al.* (2011)	Rheological behaviour of low-fat dairy dessert with various concentrations of sucrose, flavour aroma and inulin (3, 4.5, 6, 7.5, 9 percent) but with fixed amounts of skimmed milk and starch	Flow and viscoelastic parameters varied among samples depending on inulin and sucrose concentration. According to sensory results, thickness suitability varied greatly between samples. Better results were obtained by the samples containing intermediate amounts of inulin
Pasta Brennan *et al.* (2004)	Textural properties and starch degradation *in vitro* in inulin-enriched pasta (2.5, 5.0, 7.5 and 10 percent) and control pasta without inulin	Higher inulin concentrations increased dry mass content, but decreased firmness, digestion time and glycaemic index ($p < 0.05$)
Breakfast cereal Brennan *et al.* (2008)	Physicochemical analysis and *in vitro* hydrolysis of cereal starch in extruded breakfast cereal products containing different concentrations of various types of fibre, including inulin (5, 10 and 15 percent)	Inulin increased density, crunchiness and reduced adhesiveness, hardness, of products when compared to control. Inulin addition reduced humidity levels both in raw products and after extrusion. After extrusion, samples containing inulin had higher volume and viscosity, but lower digestion time. No p values were reported
Corn snacks Capriles *et al.* (2009)	Texture profile, colour, sensory analysis, chemical composition and *in vitro* starch digestion rate of corn snacks containing 2 g of inulin and 2 g oligofructose	Regarding flavour, the samples containing inulin presented lower acceptance, but lower fat content. No p values were reported
Cereal bar Dutcosky *et al.* (2006)	Sensory analysis, viscosity and chemical composition of cereal bars formulated with 13.5 percent inulin, inulin and oligofructose (6.75 percent each), inulin and *acacia gum* (6.75 percent each), and inulin, oligofructose, and *acacia gum* (4.5 percent each)	Statistically different sensory attributes in the samples with inulin were appearance (brightness, moisture), flavour, sweetness, crunchiness and texture (hardness and chewiness)

(*continued*)

Table V.

Product/author/year	Study's main features	Relevant results
Chocolate bar Gomes *et al.* (2007)	Rheological and sensory characteristics of diet and light chocolate bars containing inulin and different bulk agents: saccharose (control), polydextrose (48.27 percent), polydextrose (32.60 percent) and lactitol (15.57 percent), polydextrose (26.27 percent), lactitol (12.00 percent) and fructooligosaccharides (10.00 percent), polydextrose (24.14 percent) and inulin (24.13 percent), inulin alone (48.27 percent), inulin (32.60 percent) and lactitol (15.57 percent), inulin (32.60 percent) and maltitol (15.57 percent), polydextrose (32.60 percent) e maltitol (15.57 percent)	The only sample which presented significant difference when compared to control was the one containing polydextrose and inulin, but its humidity was higher than ideal for chocolate. For other analyses, no other characteristic presented significant differences
Wafer crackers Hempel *et al.* (2007)	Rheological analyses of dough, texture profile and sensory analysis of wafer crackers with different flour types and inulin from freeze-dried Jerusalem artichoke syrup (67.6 percent) or Jerusalen artichoke ultrafiltered freeze-dried syrup (81.8 percent)	No significant differences were found regarding rheological analysis and humidity. Firmness was higher in the crackers containing the ultrafiltered freeze-dried syrup, but they had less uniform surface and flavour
Dairy dessert (II) Lobato *et al.* (2009)	Texture profile, syneresis, colour and sensory analysis of dairy dessert with different quantities of inulin, starch and/or powdered milk	Samples containing more inulin presented higher cohesiveness and syneresis values (statistically significant results). Significant differences were not observed for other parameters
Chocolate cake Moscatto *et al.* (2004)	Texture profile, volume, physicochemical and sensory analyses, as well as shelf life of a control chocolate cake and chocolate cakes containing 20 percent *yacon* flour or 40 percent *yacon* flour plus 6 percent inulin	Formulation containing *yacon* and inulin presented lower energy value (24 percent), higher fibre and protein content than control, but lower preference scores
Pie dough Pinto and Paiva (2010)	Sensory analysis using the Quality Function Deployment (QFD) method of two formulations of ready to bake pie dough; one containing fat and 6.54 percent inulin, and other containing only 7.1 percent inulin	Sensory analysis found no significant difference in the quality of dough formulations

(*continued*)

Table V.

Product/author/year	Study's main features	Relevant results
Muffin Zahn *et al.* (2010)	Effect of inulin as a fat replacer (50, 75 or 100 percent baking fat) on baking characteristics, texture and sensory properties of muffins	With increasing amounts of added inulin, product moisture and crumb density increased significantly, whereas muffin volume decreased. Quantitative descriptive analysis revealed significant effects on product appearance, sensory texture properties, and smell and taste. Replacement of 50 percent baking fat resulted in muffins that were comparable or slightly higher in crumb firmness. Complete elimination of baking fat with inulin and water led to products which were downgraded because of high toughness, low volume and lack of a product-typical taste
Guava mousse Buriti *et al.* (2010a)	Effects of refrigeration, freezing and substitution of milk fat by inulin (0, 1.33, 2, and 4 percent) and whey protein concentrate (WPC) on the texture and sensory features of symbiotic guava mousses supplemented with the probiotic *Lactobacillus acidophilus* La-5, and the prebiotic fibre oligofructose	Frozen storage (-18 ± 1°C), followed by thawing at 4°C before the analyses, and the complete replacement of the milk fat by inulin plus WPC, led to significant differences in the instrumental texture parameters of mousses ($p < 0.05$). Changes did not affect the sensory acceptability of the products studied. To obtain a texture profile similar to the traditional product, the simultaneous addition of inulin and WPC is recommended only for the partial replacement of milk fat in refrigerated and frozen mousses, and the total proportion of both ingredients together should not exceed 2.6 percent

Cow's milk yogurt, frozen yogurt and fresh cream cheese were the other products with high protein content which had inulin added to their composition, in percentages varying from 1 to 6 per cent.

All three performed sensory analysis, but the only frozen yogurt obtained higher acceptance scores in the inulin samples, regarding aeration and creaminess parameters. Viscosity of frozen yogurt and yogurt was evaluated, and the samples containing inulin had higher scores when compared to the controls. Firmness of yogurt and fresh cream cheese was evaluated, and was higher the inulin-added samples of the former and indifferent in the samples of the latter.

The four papers about products with high fat content (Table IV) reported the development of meat products with inulin quantities varying from 2.5 to 12.5 per cent. The only work that evaluated pH and found differences in pH of products with and without inulin was that of Beriain *et al.* (2011). They observed that samples with the highest percentage of inulin (10 per cent) had significantly lower pH values than control samples without inulin. Regarding colour, Nowak *et al.* (2007) observed lower luminosity in the samples containing 6 and 12 per cent inulin when compared with the control sample. Beriain *et al.* (2011) observed that b^* values (System CIE L^*, a^*, b^*), were smaller in the samples containing 6 and 10 per cent inulin.

Texture was evaluated in three papers (Garcia *et al.*, 2006; Nowak *et al.*, 2007; Beriain *et al.*, 2011). Higher quantities of inulin (9 and 12 per cent) were found to increase adhesiveness and hardness (Nowak *et al.*, 2007). Cohesiveness and gomosity did not differ in the products with and without inulin or were higher in the control samples (Garcia *et al.*, 2006; Nowak *et al.*, 2007). Chewability was higher in the control samples (Beriain *et al.*, 2011).

Sensory analysis was performed in all four papers regarding products of high fat content, and two of them did not find any difference between samples with and without inulin. In the paper by Garcia *et al.* (2006), the samples with the highest percentage of inulin (7.5 per cent) obtained the higher scores for hardness. Nowak *et al.* (2007) found that the samples containing the highest percentage of inulin (9 and 12 per cent) were the most accepted. It was observed that the higher the inulin content, the lower were energy and lipid values.

A total of 13 papers presented results of the development of products with high carbohydrate content (Table V), and, the same as with the other groups, inulin quantities varied greatly (from 1.5 per cent in mashed potato to 32 per cent in chocolate bar), but most products contained around 10 per cent inulin.

In this group of products, ten papers presented sensory analysis results, and five of them did not observe significant differences when comparing samples with and without inulin (chocolate bar, wafer crackers, dairy desert #2, chocolate cake and pie dough). In three products the highest scores were obtained by the samples containing inulin (guava mousse, dairy desert #1 and cereal bar), and in two products the lowest flavour scores were obtained by the samples containing inulin. Therefore, one can argue that inulin addition either was not perceived or improved sensory characteristics.

Regarding texture profile, most evaluated parameters were viscosity, firmness and hardness. Viscosity was evaluated in four products, two of them did not find significant differences (pasta and chocolate bar), the other two found discrepant results. In one of them viscosity was higher (dairy desert #1) and in the other (breakfast cereal) it was lower in the samples containing inulin.

Firmness was a parameter evaluated in four products, and in all of them it was higher in the samples containing inulin (mashed potato, wafer crackers, muffin and guava mousse).

Hardness was also evaluated in four products and only in one of them (chocolate bar) the sample containing inulin did not present difference when compared with the control sample. In breakfast cereal, chocolate cake and guava mousse inulin addition reduce products' hardness.

Humidity was evaluated in six products, and in four of them it was higher in the samples containing inulin (corn snack, chocolate bar, chocolate cake, and muffin). In the breakfast cereal humidity decreased in the samples with inulin, and in the wafer crackers differences were not significant.

Two papers compared energy, fat, fibre and protein content of the samples (chocolate cake and corn snack). In both of them, energy and lipid content were smaller and fibre content was higher in the samples containing inulin. Protein content did not differ.

In the three groups of products presented in Tables III-V, the most frequent analysis was the sensory (15 products out of 22). Generally speaking, developed products containing inulin either did not differ or received better scores in sensory evaluation, suggesting that inulin addition is in fact an alternative for ingredient substitution once its presence was not perceived or increased acceptance.

Specifically in the group of products with high fat content, where pH and colour analyses were the second more frequent, inulin addition did not significantly alter these parameters.

Regarding the products with high protein and carbohydrate content, where texture profile analyses were the second more frequent, and inulin addition modified viscosity, elasticity and firmness in erratic ways, therefore it is not possible to state that its effect was positive or negative.

Conclusion

Each group of products studied employed a different percentage of inulin, indicating that food composition determines the necessary amount of inulin to induce the desired changes. Inulin quantities added to products varied from 0.2 to 32 per cent among the 28 products presented in the selected papers. The smallest variation and percentages were observed in the products with high protein content (from 0.5 to 4.43 per cent). Highest variation and added quantities were observed in the group of products with high carbohydrate content. Therefore, little amounts of inulin are enough to alter physicochemical characteristics of products with high protein content, while higher quantities are necessary to induce changes in the products with high carbohydrate content.

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