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ORIGINAL RESEARCH

Sensory quality and consumer acceptance of skim yoghurt produced with transglutaminase at pilot plant scale

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*The aim of this work was to obtain information about how sensory differences affect consumer acceptability for skim yoghurt obtained with transglutaminase (TG yoghurt). Skim yoghurt fortified with skim milk powder was used as control (Control yoghurt). Sensory descriptors were assessed by a trained panel (*n = *16). Acceptance and preference were evaluated by consumers (*n = *124). Results showed that TG yoghurt showed a sensory profile different to that of Control yoghurt. TG yoghurt was firmer and less creamy than Control yoghurt. The acceptance index was 59.7% for TG yoghurt and 70.5% for Control yoghurt. Consumers did not show a high rejection towards TG yoghurt.*

Keywords Sensory quality, Acceptance index, Risk–opportunity, Preference, Transglutaminase, Yoghurt.

INTRODUCTION

Yoghurt is a dairy product obtained by lactic fermentation of milk. The fermentation is produced by the addition of a starter culture containing the bacteria *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The process is carried out at controlled temperature, which causes a pH drop until 4.6. The texture and other sensory properties of yoghurt make it a product with specific sensory properties (Muir *et al.* 1999; Vázquez-Velázquez *et al.* 2018). Yoghurt is one of the most popular fermented dairy products around the world. It has an important role in daily diet supplying nutrients in a bioavailable form. It has gained consumer acceptance as a healthy food. In addition, yoghurt has many health benefits such as improving lactose tolerance and others related to probiotic bacteria (Buttriss 1997; Onwulata *et al.* 1989). Particularly, low-fat varieties provide important nutrients in significant amounts in relationship with their energy and fat content, making them a nutrient-dense food (McKinley 2005; Serafeimidou *et al.* 2013). Yoghurt has traditionally been considered a pleasant and a convenient product, with an attractive sensory quality (Sahan *et al.* 2008; Loveday *et al.* 2013).

In addition to being healthy, consumers expect to obtain pleasure from food intake; hence, food must have good sensory characteristics (Verbeke 2006). Food companies should know and understand the needs, likes and preferences of consumers to satisfy them. It is to understand the key sensory descriptors of importance to consumers in order to avoid failure of a new product (Grygorczyk *et al.* 2013).

The demand of low-fat or skim yoghurts is increasing, but these products have a different texture compared with regular-fat ones; common defects are in texture and syneresis (Pereira *et al.* 2006; Lee and Lucey 2010). The decrease in fat content or its replacement by texturising agents can lead to change in the distribution of taste and aroma molecules within the product and lead to differences in taste and aroma perception (Routray and Mishra 2011). Due to texture and syneresis are fundamental in yoghurt acceptance, researchers have investigated effects of fat replacement with several milk ingredients such as nonfat dry milk, milk

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protein concentrate and whey protein concentrate (González-Martínez *et al.* 2002; Kavas *et al.* 2003; Yazici and Akgun 2004; Pereira *et al.* 2006); additives as gelling, thickening or stabilising agents (Lucey and Singh 1997); and water-soluble macromolecules or hydrocolloid as gelatin, pectin or inulin (Everett and McLeod 2005; Paseephol *et al.* 2008; Shi *et al.* 2017a,b). However, textural defects associated with these fat replacers were still detected by consumers (Guzmán-González *et al.* 2000; Kavas *et al.* 2003; Sandoval-Castilla *et al.* 2004; Lee and Lucey 2010).

In conventional yoghurt manufacture, the protein gel is mainly stabilised by weak noncovalent interactions (electrostatic, hydrogen bonding, hydrophobic bonds). The use of the enzyme microbial transglutaminase (TG) allows to introduce new covalent bonds leads to gel formation with different structure and properties (Schorsch *et al.* 2000; Farnsworth *et al.* 2006). Thus, TG is considered as an effective alternative to these fat replacers (Yokoyama *et al.* 2004; Jaros *et al.* 2006; Ozer *et al.* 2007; Yüksel and Erde 2010;; Jooyandeh *et al.* 2015). TG catalyses an acyl-transfer reaction between the carboxyamide group of peptides bound glutamine residues (acyl donors) and a variety of primary amines (acyl acceptors), including the amino group of lysine residues in certain proteins. In the absence of amine substrates, TG catalyses the deamination of glutamine residues and water molecules are used as acyl acceptors. TG can modify proteins by means of amine incorporation, crosslinking and deamination (Motoki and Seguro 1998). Due to its great potential to improve various functional properties of proteins, TG is mainly used to enhance texture, stability and water binding (Dube *et al.* 2007). Casein from milk is an excellent substrate for TG (Motoki and Seguro 1998; Routray and Mishra 2011).

Sensory evaluation is a useful tool for food manufactures to measure consumer acceptance and product quality (Sidel and Stone 1993; Murray *et al.* 2001). The strategy most acceptable for sensory quality evaluation considers the relationship between two types of data: consumer test (affective or hedonic test) and trained analytical panel (descriptive or analytic test). The comparison between both (affective and descriptive tests) allows to obtain products with sensory profiles well adapted to the target market, enabling food companies to launch control activities, improve quality and develop new products (Elortondo *et al.* 2007; Semeniuc *et al.* 2016). Trained assessors can describe the product differently or take into account sensory descriptors that may be irrelevant for consumers (ten Kleij and Musters 2003; Ishii *et al.* 2007). Affective testing from untrained respondents is used to evaluate consumers' acceptance, preference and expectations since hedonic characteristics can be generated by a variety of factors. Hedonic characteristics play an important role in food selection and consumption (Bayarri *et al.* 2010).

Identifying the key sensory characteristics that affect or determine consumer preferences can provide useful tool for food manufactures (Masson *et al.* 2016). The goal of this study was to determine the effect of TG used as fat replacer in skim yoghurt on sensory quality and consumer acceptance. The use of TG avoids the fortification with skim milk powder.

MATERIALS AND METHODS

Raw materials

Skim milk was measured before use obtaining the following composition: fat, 0.04 %; protein, 3.30%; total dry matter, 9.35%. Microbial transglutaminase (Probind®) was supplied by BDF Natural Ingredients (Girona, Spain). The activity measured before use was 66 U/g. A colorimetric procedure was used to determine enzyme transglutaminase activity before use. Briefly, N-α-CBZ-gln-gly (Sigma-Aldrich Corp, St. Louis, MO, USA) was used as substrate. A calibration curve was made using L-glutamic acid γ-monohydroxamate (Sigma-Aldrich Corp, St. Louis, MO, USA). One unit of transglutaminase is defined as the formation of 1 micromol l-glutamic acid γ-monohydroxamate in 1 min at 37 °C (Grossowicz *et al.* 1950).

Preparation of yoghurts

The manufacturing of yoghurts was performed in a pilot plant (Aula de productos lácteos, USC, Lugo, Spain). The skim milk (120 L) was split into two batches, one of 60 L for skim yoghurt obtained with transglutaminase (TG yoghurt) and the other of 60 L for skim yoghurt without enzyme (Control yoghurt). For the Control yoghurt batch, the milk was fortified with skim milk powder to increase the dry matter without increasing fat prior to the heat treatment as it was done in the yoghurt manufactured. It was blended with skim milk powder to achieve the following values: 0.05 % fat; 3.80 % protein; 10.45 % total dry matter. For TG yoghurt batch, it was used a dose of 0.76 U per g of milk protein. The dose was calculated after conducting preliminary studies (García-Gómez *et al.* 2018, 2019).

Both batches were pasteurised at 95 °C for 5 min and homogenised at (200 + 50) bar. Then, they were cooled at 43 °C. Freeze-dried lactic culture (LyoCulture Dairy, BDF Natural Ingredients, Girona, Spain) at 0.2 g/L of milk was inoculated and blended into the milk. Inoculation of TG was simultaneously added with the starter culture. The mixture was poured into 125-g plastic cups and incubated at 43 °C. Each batch was formed by 360 yoghurts. The coagulation of milk was monitored by pH change during the incubation period until a pH of 4.6 was attained. TG was gradually inactivated with the decrease in pH. TG activity was not detected at the end of the fermentation. Then, yoghurts were moved to a cool room and stored at 4 °C. Samples were evaluated by the consumers and the trained panel after 5 days to allow a good setting of the yoghurts.

Table 1 Definition and evaluation procedure for the sensory descriptors considered in this work.

Descriptor	*Definition*	*Scale and references*	
Odour whey	Odour perceived when holding the yoghurt close to the nose caused by the whey produced in the yoghurt process	0 = Diluted yoghurt whey (1:4)	10 = Yoghurt whey
Firmness	Force required to lift the product with a coffee spoon	0 = Custard	10 = Vanilla flan
Density	Perception of compactness and body after introducing the sample in the mouth and compressed it between the tongue and the palate	0 = Curd	10 = Petit Suisse
Creaminess	Perception of thickness and smoothness pressing the sample between the tongue and palate	0 = Curd	10 = Mayonnaise
Acid taste	Basic taste similar to that produced by dilute aqueous solutions of citric acid	0 = 0.13 g/L citric acid solutions	10 = 0.60 g/L citric acid solutions
Bitter taste	Basic taste similar to that produced by dilute aqueous solutions of caffeine	0 = 0.03 g/L caffeine solutions	10 = 0.17 g/L caffeine solutions
Astringency	Shrinking or drying effect on the mouth surface caused by produced by dilute aqueous solutions of tannic acid	0 = Not detected	10 = 0.1 g/L tannic acid solutions
Persistency	Time of persistence of the olfactory/gustatory sensation perceived after the bolus has been swallowed or ejected	0 ≤ 20s	10 ≥ 60s

Descriptive sensory analysis

Simultaneously to the consumer test, the samples were evaluated by 17 trained panellists with previous experience defining yoghurt′s sensory profiles. Analytical sensory evaluation was performed using quantitative descriptive analysis (QDA). Panellists were screened previously based on their availability and their sensory acuity. Then, panellists were trained about basic tastes, odours, texture and scaling exercises (Meilgaard *et al.* 2000; AENOR 2014b). The procedures for selection and training were performed according to international rules (AENOR 2014b). The trained panel generated the set of sensory descriptors (AENOR 2018), scales and references to evaluate the sensory profile. Panellist evaluated the intensity of the terms for each sample using an unstructured 10-cm-line scale ranking according to the references previously determined for all sensory descriptors.

After 20 h of training in the selected set of sensory descriptors, the panel performance was assessed to ensure the reliability of the results of the analysis. The panel performance allowed to provide feedback to each panellist that permitted a self-correction.

Assessments were performed in a standard sensory laboratory room (AENOR 2010, 2014a) equipped with ten isolated taste booths. Each sample was labelled with random 3-digit codes, and the evaluations were performed in accordance with a randomised complete block experimental design to avoid artefacts due to order of sample presentation. Water was provided to clear palate between sample evaluations. The samples were presented to the panellists in 125-g plastic cups, and the serving temperature of the samples was 8 °C. The assessors used the same standard references in all sessions to evaluate each descriptor. Definitions and evaluation procedure are shown in Table 1.

Consumer panel analysis

Consumers (n = 124) were recruited for a hedonic laboratory test. Testing was conducted in Lugo (NW Spain). The criterion of recruitment has been being habitual consumer of yoghurt. Respondents were 64.5% women and 35.5% men. They aged between 18 and 39 years old (37.9%), 40-59 years old (39.5%) and over 60 years old (22.6%).

Samples (TG and Control) presentation was carried out at 8 °C in 125 g covered plastic cups. Samples were randomly presented using a 3-digit code in a sequential monadic way using a balanced complete block design. Appearance, odour, taste, texture and overall acceptability (Majchrzak *et al.* 2010) have been assessed using a 9-point hedonic scale (1–dislike extremely, 2–dislike very much, 3–dislike, 4–dislike slightly, 5–neither like nor dislike, 6–like slightly, 7–like, 8–like very much and 9–like extremely) for the acceptance test.

Participants were asked about purchasing habits and frequency and motivation for yoghurt consumption. Respondents were also asked about their preference, if they would consume any of the yoghurts or if they would totally discard some of them, as well as the reasons for choosing or discard them.

Statistical analysis

All statistical calculations were performed using IBM SPSS Statistics 20 software for Windows (IBM, Armonk, NY, USA) and R Project (www.r-project.org). Differences at a level of $P < 0.05$ were considered significant. The Student

t-test was carried out in order to evaluate statistically significant differences between TG yoghurt and Control yoghurt. The Spearman's correlation coefficient was used to assess the appearance, odour, taste and texture relation with overall acceptance.

Differences between TG sample and Control in consumers were studied by Wilcoxon's signed-rank test (Wilcoxon 1945). Mean and standard deviation were calculated for the quantitative descriptive analysis and consumer test in order to summarise panellist and consumer responses and to calculate the acceptance index. An opportunity analysis (Rothman and Parker 2009) was applied to study how the degree of acceptance of TG yoghurt could be increased by modifying some of its sensory descriptors.

RESULTS AND DISCUSSION

Quantitative descriptive analysis

Sensory patterns obtained by the trained panel are shown in Figure 1. TG yoghurt showed more firmness than Control yoghurt. TG yoghurt was less creaminess and dense. Control sample showed high scores in odour whey, and it was pointed as more acid taste and bitter taste than TG yoghurt. The Student *t*-test showed statistically significant differences for many of the sensory descriptors evaluated: odour whey ($P = 0.0099$**); firmness ($P = 0.0003$***); density ($P = 0.0069$**); creaminess ($P = 0.0010$**); acid taste ($P = 0.0001$***); bitter taste ($P = 0.0048$); and persistency ($P = 0.0191$*). The definitions of these descriptors are shown in Table 1. Results agree with the literature that reported an effect of TG addition on texture, increasing firmness, consistency and decreasing free whey and odour (Sodini *et al.* 2004; Ozer *et al.* 2007; Şanli *et al.* 2011; Domagała *et al.* 2013).

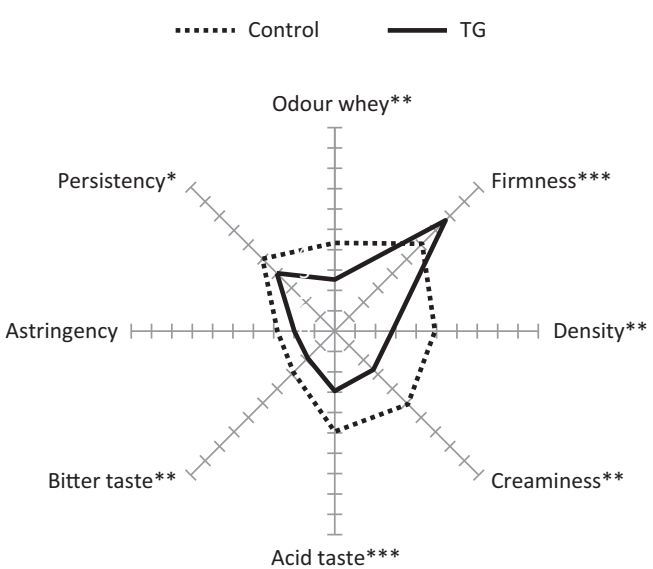

Figure 1 Sensory pattern of yoghurt treated with transglutaminase (TG yoghurt) and yoghurt without transglutaminase (Control yoghurt) obtained in the quantitative descriptive analysis.
*P-value < 0.05, **P-value < 0.01 and *P-value < 0.001.

Consumer evaluation

Consumers evaluated the yoghurt samples about appearance, odour, taste, texture and overall acceptance. The mean for odour, taste and texture was lower for the TG yoghurt than Control yoghurt (Table 2). Wilcoxon test was performed in order to evaluate possible differences in the acceptance of both yoghurts. The odour, taste, texture and overall acceptance were significantly higher for the Control yoghurt than TG yoghurt (P-value < 0.05, P-value < 0.0001, P-value < 0.0001 and P-value < 0.0001, respectively). Results showed no significant differences between appearance acceptability of TG yoghurt and Control yoghurt. The texture is a determining sensory descriptor for the acceptance of yoghurt (Sodini *et al.* 2004). Only 29.8% of respondents preferred TG yoghurt over Control yoghurt. 26.6% of respondents claim that they would consume TG yoghurt; meanwhile, 53.2% of respondents claim that they would consume the Control yoghurt. It is important to note that only 28.2% and 12.1% of respondents would totally discard for their consumption the TG yoghurt and the Control yoghurt, respectively.

The main reasons that would motivate the consumption were the pleasant taste and texture and a health motivation. The comparison of proportions has shown that consumers preferred control sample (P-value < 0.0001). Results obtained in the preference test and the overall acceptance scores were consistent since consumers preferred Control yoghurt and the overall acceptance for Control yoghurt was higher than TG yoghurt.

Analysing the overall acceptance scores (Table 3), it was observed that 29.8% of the consumers placed the TG yoghurt in the zone of rejection of the scale (<5), while only 8.9% of the consumers placed the Control yoghurt in this zone. Whereas in the region of the scale of high acceptance (8–9 points) only 5.6% of the consumers selected the TG yoghurt. The acceptance index summarises the

Table 2 Affective scores (mean and standard deviation) obtained for the yoghurt treated with transglutaminase (TG yoghurt) and the yoghurt without transglutaminase (Control Yoghurt). Mean ± standard deviation.

Descriptor	*TG yoghurt*	*Control yoghurt*
Appearance	6.52 ± 1.27	6.17 ± 1.32
Odour	6.01 ± 1.26	6.36 ± 1.36
Taste	5.23 ± 1.59	6.10 ± 1.51
Texture	5.31 ± 1.72	6.56 ± 1.51
Overall acceptance	5.37 ± 1.56	6.35 ± 1.26

Table 3 Distribution scores for transglutaminase (TG) and Control yoghurts and acceptance index.

TG Yoghurt					*Control Yoghurt*			
Scale	*Consumers*	*Score*	*Average*	*Acceptance Index*	*Consumers*	*Score*	*Average*	*Acceptance Index*
1	2	2	0.02	0.18	0	0	0.00	0.00
2	3	6	0.05	0.54	1	2	0.02	0.18
3	8	24	0.19	2.15	2	6	0.05	0.54
4	24	96	0.77	8.60	8	32	0.26	2.87
5	26	130	1.05	11.65	16	80	0.65	7.17
6	26	156	1.26	13.98	32	192	1.55	17.20
7	28	196	1.58	17.56	46	322	2.60	28.85
8	7	56	0.45	5.02	18	144	1.16	12.90
9	0	0	0.00	0.00	1	9	0.07	0.81
Total	124	666	5.37	59.68	124	787	6.35	70.52

acceptance results from the distribution scores (Carbonera *et al.* 2014). The acceptance index was 59.7% for TG yoghurt and 70.5% for Control yoghurt.

The Spearman's correlation coefficient (P-value < 0.01) showed a high correlation between overall acceptance of TG yoghurt with taste (r = 0.845) and texture acceptance (r = 0.691). Control yoghurt showed a slight lower correlation (p-value < 0.01) between overall acceptance and the same sensory descriptors (r = 0.790 and r = 0.630, respectively). The results of both acceptance and preference clearly placed the TG yoghurt in an inferior position to the Control yoghurt.

Due to the observed relationship between taste and texture with overall acceptance, a modification of any of them could be an opportunity to increase global acceptance. However, the opportunity analysis has shown that this is not the case because a reformulation of the product that involves changes in the taste and texture would assume a very high risk of a global acceptance decrease. The reason is that texture and taste have been the most scored sensory descriptors for TG yoghurt by consumers that showed the greatest acceptability for the TG yoghurt (Figure 2).

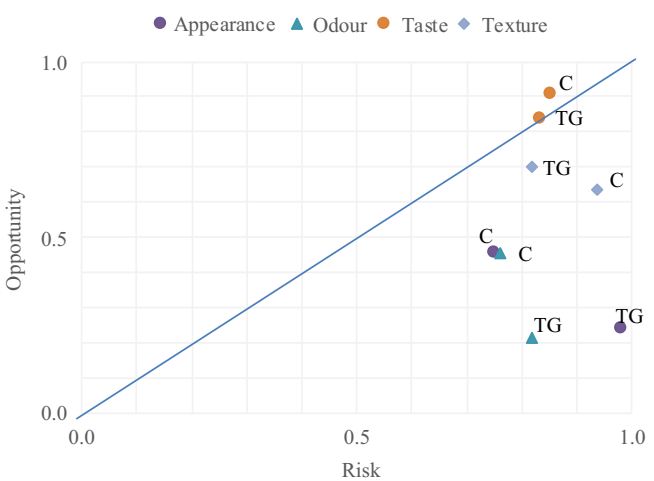

Figure 2 Opportunity analysis for transglutaminase (TG) yoghurt (C: yoghurt without TG; TG: yoghurt with added TG). [Colour figure can be viewed at wileyonlinelibrary.com]

Relationship between acceptability, preference and sensory attributes

The importance of sensory attributes in the acceptance of a food product was confirmed by several studies (Duboc and Mollet 2001; Sodini *et al.* 2004; Janhøj *et al.* 2006; Jaworska and Hoffmann 2008; Vargas *et al.* 2008; Bayarri *et al.* 2011; Routray and Mishra 2011). However, large differences have been found between the ideal product for different consumer clusters (Bayarri *et al.* 2011; Masson *et al.* 2016).

Consumers showed greater acceptance of Control yoghurt against TG yoghurt, which suggests that in terms of texture, they prefer a creamy yoghurt, dense and not too firm. In terms of taste, they like to have a slight acidity, bitterness and astringency, intrinsic characteristics of conventional natural yoghurt. The importance of the texture was confirmed by several studies, specifically the creaminess and the firmness in dairy products (Barnes *et al.* 1991; Harper *et al.* 1991; Duboc and Mollet 2001; Janhøj *et al.* 2006; Jaworska and Hoffmann 2008; Vargas *et al.* 2008).

It was also confirmed that the aroma (Routray and Mishra 2011), acidity and bitterness are key in overall acceptance (Barnes *et al.* 1991; Bayarri *et al.* 2010). Astringency affects acceptance (Bayarri *et al.* 2010) although in excess it is considered a defect in yoghurt (Lemieux and Simard 1994).

CONCLUSIONS

Transglutaminase yoghurt showed different sensory descriptors than the Control yoghurt obtained with skim milk powder. TG yoghurt was firmer and less creamy than the Control yoghurt. These sensory descriptors could decrease

the acceptance and preference of the TG yoghurt. Texture and taste have been the most scored sensory descriptors for TG yoghurt by consumers that showed the greatest acceptability for the TG yoghurt. Consumers do not show a high rejection towards TG yoghurt. The acceptance index was 59.7% for TG yoghurt and 70.5% for Control yoghurt. The information obtained can be important to predict or explain the market response to TG yoghurts.

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