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Towards an increased plant protein intake: rheological properties, sensory perception and consumer acceptability of lactic acid fermented, oat-based gels

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Abstract:

In general, the interest in food that contains a reasonable amount of plant protein is steadily increasing. As a consequence, products with pleasant texture and taste ensuring a high consumer acceptance are needed. The aim of the present study was to develop and characterize structural differences and organoleptic impressions of lactic acid fermented, oat-based gels which could serve as plant protein enriched, non-dairy yoghurt alternatives. Oat protein concentrate, a by-product of cereal processing, was used as plant protein source. It was shown that total solids content had the highest impact on rheological properties. All samples were described as soft fluid gels and their structure was dominated by the heat-induced gelation of starch. Within this mixed food system of starch and protein, swollen starch granules, protein aggregates and residual small fat droplets were embedded in a rough macromolecular network of leached amylose. They acted as filler and increased the rigidity (G') of the system. Native starch content determined the water holding capacity with an increase in water binding with increasing concentration. Overall, rheological characteristics were found to be strongly linked to the products' textural attributes which, in turn, determined consumer acceptability. For the purpose of product development, overall liking was influenced by the quantifiable sensory attributes – sweet, moist, soft, and smooth. Purchase intention, however, was positively influenced by the extrinsic attribute information (on oat protein enrichment). These data, in combination with the impact of the identified ingredients on product structure, are a valuable tool to improve product properties, consumer perceptions and product acceptability. To conclude, lactic fermented, oat-based gels can serve as a plant-based yoghurt-alternative that combines nutritional benefits with good textural properties.

Keywords: fermentation; oat protein concentrate; oat-based gel; rheological properties; sensory attributes; consumer acceptability

1. Introduction

In developed countries, diets high in processed and red meat have contributed to an increasing prevalence of obesity (Rouhani, Salehi-Abargouei, Surkan, & Azadbakht, 2014; Wang & Beydoun, 2009) and to a positive association with the risk of pancreatic cancer (Larsson & Wolk, 2012). In addition, when compared to plant-based food, food based on animal protein has a higher energy consumption and increased GHG emissions (González, Frostell, & Carlsson-Kanyama, 2011). Consequently, diets high in plant-based proteins are increasingly recommended not only for health but also for environmental reasons. The partial or full replacement of animal proteins in foods and the development of innovative plant protein-based foods with high consumer acceptance is, therefore, a major issue. In this context, health claims in labelling are of major importance as people can then easily identify the content of macro-nutrients, for instance protein, in a food product. According to the EU regulation on nutrition claims (Regulation (EC) No 1924/2006, amended by Regulation (EU) No 1047/2012), two health claims related to protein are allowed: the claim that a food is a “source of protein” (>12% of the energy value of the product is provided by protein) or is “high in protein” (> 20% of the energy value of the product is provided by protein).

In the context of identifying high protein products with good consumer acceptance, a focus group study has shown that yoghurt, amongst other products, was the most accepted semi-solid food which was already associated with a high protein content (Banovic et al., 2018). When it comes to the protein source, oat (*Avena sativa* L.) is a favorable ingredient. Oat is highly accepted by consumers (Banovic et al., 2018), has a high protein content of between 12 and 15% (Mäkinen, Sozer, Ercili-Cura, & Poutanen, 2017), and a high nutritional value with a good amino acid balance (Rasane, Jha, Sabikhi, Kumar, & Unnikrishnan, 2013). The obvious approach is, therefore, to use oat as a protein source for the development of a high protein, lactic fermented gel. Hence, a fraction being rich in oat protein, an oat protein concentrate (OPC), can serve as a raw material. OPC is a mixture of oat protein and starch. During acidification, oat protein was found to form aggregates which were poorly incorporated into the casein network of a classic cow milk yoghurt and were not able to form a stable network; strong sedimentation occurred. However, upon gelatinization the starch fraction present in OPC was able to compensate the incompatibility of milk proteins and oat protein due to increased viscosity (Brückner-Gühmann, Benthin, & Drusch, 2019). For a plant-based gel made of OPC, it is very likely that the gelatinized starch fraction will be able to form a network with integrated oat protein resulting in superior textural attributes.

However, in plant-based fermented, oat-based gels, the development of stable texture and superior sensory quality were found to be the main challenges reported in literature for soy (Bedani, Vieira, Rossi, & Saad, 2014; Buono, Setser, Erickson, & Fung, 1990; Donkor, Henriksson, Vasiljevic, & Shah, 2007), other legumes (Rao, Pulusani, & Chawan, 1988), oat bran (Blandino, Al-Aseeri, Pandiella, Cantero, & Webb, 2003) and oat (Mårtensson, Andersson, Andersson, Öste, & Holst, 2001). None of the products from these studies was claimed to be a “source of protein” or “high in protein” product. Textural attributes obtained by rheological measurements should be directly used to characterize a specific product quality and predict its consumer acceptability. For a newly developed product, among others, check-all-that-apply (CATA) can be used to measure consumer perceptions and product acceptability with untrained people (Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010) enabling the direct identification of key drivers of liking and generating information on perceived quality attributes without the need for the normal scaling procedures (when intensities are assigned to each attribute of the tested product). Generally, familiarity with a product, health and nutrition claims, functionality and personal relevance can positively influence the intention to purchase a product (Wills, Storcksdieck genannt Bonsmann, Kolka, & Grunert, 2012). Moreover, products with an overall positive health image, like bread or yoghurt, were rated more positively when they came with health claims (Siegrist, Stampfli, & Kastenholz, 2008; van Kleef, van Trijp, & Luning, 2005). Nevertheless, the adoption of a plant-based diet was found to be hindered by various obstacles including eating routines and difficulties in preparing vegetarian foods (Pohjolainen, Vinnari, & Jokinen, 2015). Previously, information disclosure (i.e. extrinsic attributes such as origin, health claims) has been shown to have a significant effect on product quality perceptions and sensory evaluations (Banović, Fontes, Barreira, & Grunert, 2012; Grasso, Monahan, Hutchings, & Brunton, 2017). A key step in product development is the selection of a product formulation that is aligned with consumer perceptions and preferences (Banović, Krystallis, Guerrero, & Reinders, 2016). This involves a good grasp of consumer perception of both the sensory attributes traditionally included in the consumer tests coupled with validation efforts if information disclosure, for example health claims related to the protein content, could alter or improve product liking and acceptability. Therefore, the impact of information disclosure on the willingness to buy plant protein enriched products will be explored. To the best of our knowledge, this study is the first to analyze the impact of the inclusion of health claims about protein content on the intention to purchase a lactic fermented oat-based gel as a plant-based yoghurt-alternative.

The aim of this study was to analyze structural differences and organoleptic impressions which result from the variation in ingredient concentration in order to generate plant protein-based products with improved sensory quality. Therefore, two different types of fermented products based on oat protein concentrate have been developed which would permit the claim that the product is either a "source of protein" (SoP) (>12% of the energy value of the product is provided by oat protein) or "high in protein" (HiP) (> 20% of the energy value of the product is provided by oat protein). We hypothesize that textural attributes obtained by rheological measurements as well as compositional parameters (lactic acid content, total solids content), in combination with consumer perception, can be used to control and improve the specific product quality. Furthermore, the effect of information disclosure on oat-protein enrichments (claim product is a SoP or HiP) and its impact on product quality perceptions will be validated.

2. Materials and methods

Oat protein concentrate (OPC) was kindly provided by Fazer Mills Finland, Lahti, Finland It contained 7.90 ± 0.02% moisture, 4.94 ± 0.27% fat, 3.32 ± 0.02% ash, 28.29 ± 0.06% protein (N x 6.25), 3.64 ± 0.10% total dietary fiber and 45.30 ± 0.77% starch. The total carbohydrates content was 51.91 ± 0.15%.

2.1 Preparation of fermented, oat-based gel

OPC (12% for HiP and 10% for SoP) and 1% sugar were suspended in 2 L water (HiP) or 2 L oat drink (SoP), respectively. The oat drink (Alnatura GmbH, Bickenbach, Germany) contained 1.4% fat, 6% carbohydrates, of which 5.2% sugar, 0.5% dietary fiber, 0.6% protein and 0.13% salt. All samples were stirred for 30 min at 37 °C in the Thermomix TM31 at 250 rpm (Vorwerk, Wuppertal, Germany). Yoghurt culture (1 U for SoP and 2 U for HiP) containing *Lactobacillus delbrückii* subsp. *Bulgaricus* and *Streptococcus thermophilus* (YC-X11 Yo-Flex, Chr. Hansen, Denmark) was added. The amount of starter culture needed to sufficiently reduce the pH to 4 was determined in preliminary experiments. The samples were fermented in a water bath at 42 °C for 24 h. In order to gelatinize the starch, the samples were heated to 90 °C for 20 min. Subsequently, the mixture was hot filled into glass jars and immediately cooled to 4-6°C.

2.2 Determination of lactic acid content, pH value and total solids content

The lactic acid concentration of the fermented samples after 24 h was determined by a colorimetric assay for the determination of lactic acid in foodstuffs according to the instruction manual (R-biopharm AG, Darmstadt, Germany). The pH value was measured with pH meter Lab 865 and BlueLine 18 pH electrode (SI Analytics GmbH, Mainz, Germany). The Mettler

Toledo Infrared Dryer LP16 (Mettler-Toledo GmbH, Giessen, Germany) was used to determine the total solids content (%) at 105 °C.

2.3 Rheological measurements

Oscillatory measurements were performed using a rheometer (UDS 200, Anton Paar GmbH, Ostfildern, Germany) equipped with a Z3 DIN coaxial standard measuring cylinder (measuring gap: 1.06 mm). Frequency sweeps were done at constant deformation: γ = 10^{-3} and at frequencies between 0.01 and 10 Hz. Amplitude sweeps were carried out at a constant frequency of 1 Hz and a deformation between γ = 10^{-3} and 10. The value of deformation at $G' = G''$ or $\tan\delta = \frac{G'}{G''} = 1$ can be interpreted as the yield point according to DIN Fachbericht 143:2005-04. The the shear stress □$_0$ [Pa] at this point was further evaluated.

For thixotropy tests, the samples were oscillated (γ = 10^{-3}, f = 1 Hz for 100 s), sheared (shear rate of $\dot{\gamma}$ = 200 s^{-1} for 2 min) and oscillated (γ = 10^{-3}, f = 1 Hz for 10 min) according to DIN SPEC 91142-2:2012-09. The recovery of structure [%] was calculated for the elastic modulus G':

$$\text{Recovery of structure [\%]} = \frac{G'_{before\ shearing}}{G'_{end}} \cdot 100$$

All measurements were done in triplicate.

2.4 Water holding capacity

The water holding capacity of the samples was determined using the method of Guzmán-González et al. (1999) which we described previously in Brückner-Gühmann, Benthin and Drusch (2018).

2.5 Consumer tests

One hundred and two participants were recruited for the consumer tests in Germany. Age and gender quotas were imposed: 50% male participants and mean age of 41.5 years. All the participants were regular dairy consumers and had positive attitudes towards using plant protein for the enrichment of food products (M=5.30(1.44), scale 1 – strongly disagree, 7 – strongly agree). For validation purposes, 52 consumers were additionally recruited with the same requirements as above (i.e. 50% male, 41.9 years, regular dairy consumers) to investigate the possible impact of information on consumer acceptance of oat-protein enriched yogurts.

The samples were stored in cold conditions before the trial (6°C, 24 h) and presented at room temperature in the same standardized glass jars. The samples were blind-labelled with random three digit-codes and their order randomized to avoid order bias. Consumer tests were carried out in a tasting room in the separate testing booths under uniform, shadow-free lightning (DIN EN ISO 8589:2014-10).

For the blind tasting condition, a total of ten tasting sessions were held with approximately 10 participants per session. First, the participants were informed about the aim of the study without disclosing information about the products. Second, the participants assessed the expected overall acceptability (i.e. liking), visual appearance, flavor, texture, and overall quality on the 9-point scale with bipolar points 1- extremely dislike it, 9 – extremely like it, without actually tasting the product (Claret, Guerrero, Gartzia, Garcia-Quiroga, & Ginés, 2016). Further, they indicated their purchase intent for each product measured on the Juster's 11-point scale

(Juster, 1966), and chose the expected preferred product or none. Finally, the participants tasted each product without any information (i.e. blind tasting) and evaluated again (only this time experienced) overall acceptability (liking), visual appearance, flavor, texture, and overall quality on the 9-point scale. This was followed by a list of 16 sensory descriptors that they considered applicable to each product (check-all-that-apply or CATA) (Ares et al., 2010), and assessed purchase intent and preferred product as described above.

For the informed condition, five tasting sessions, each with approximately 10 participants, were performed to assess whether the information presented prior to the product evaluations could alter the consumer perceptions and product acceptability. The informed condition differed from the blind tasting condition in only one detail, namely that participants had been directed first to process information about the two products (i.e. SoP and HiP), and then to subsequently evaluate products following the same procedure as in the blind tasting condition. The information presented was in line with the EU regulation on nutrition claims (Regulation (EC) No 1924/2006, amended by Regulation (EU) No 1047/2012), regarding SoP and HiP products. Consequently, SoP yogurt was described as “a product where 12% of the energy value of the product is provided by oat protein”, while HiP yogurt was described as “a product where at least 20% of the energy value of the product is provided by oat protein”.

2.6 Statistical analysis

2.4.1 Composition and rheological measurements

The statistical significance between both samples in terms of composition (total solids content, lactic acid content), rheological behavior ($G'_{\text{frequency sweep 1 Hz}}$, τ_0 yield point, recovery of structure) and water holding capacity was analyzed by means of a t-test for two independent samples ($p < 0.05$) using SPSS Statistics Version 25 (SPSS Inc., Chicago, USA).

2.4.2 Consumer tests

Statistical analysis was performed with the software XLSTAT, version 2018 (Addinsoft, Paris). T-tests were used to compare the liking of SoP and HiP yogurts under the blind and informed conditions in both the expectation and experience phases, as well as between these phases. Pearson’s correlation coefficients were used to monitor the relationship between the overall products’ (i.e. SoP and HiP) liking and perceptions of visual appearance, flavor, and texture, as well as between product acceptability (in terms of purchase intention) and the blind and informed conditions. For the CATA data, first the contingency table was used to summarize the choice frequency of each attribute across consumers and for both SoP and HiP yogurts. This was followed by application of Cochran’s Q test to establish differences among the frequencies of the two yogurts. Further, as suggested by Ares, Dauber, Fernández, Giménez, and Varela (2014) and Meyners, Castura, and Carr (2013), Principal Coordinates Analysis was applied to the sensory attributes, correlation coefficients and overall liking, followed by penalty analyses.

3. Results and discussion

3.1 Composition, energy and additional ingredients

In the HiP product 28.6% of the energy value was provided by oat protein while it was 17.7% in the SoP product (see Table 1 in Suppl. material on ingredients, protein content and percentage of energy from protein in samples). Consequently, “source of protein” or “high in protein” claims were possible according to Regulation No 1924/2006. In addition, the SoP product had a significantly higher total solids content (17.8 ± 0.9%, Table 1) than the HiP (11.3 ± 0.5%, Table 1). The difference resulted from the oat drink which was used, instead of water, as a basis for the SoP sample. As a result, the SoP contained more fat, carbohydrates, dietary fiber and salt than the HiP. However, the actual amount of protein in 100 g did not differ between the two samples (see Table 1 in Suppl. material).

Lactic acid fermentation of OPC and subsequent gelatinization of the starch fraction resulted in mild acidic products with a low pH (SoP: 4.2 ± 0.0, HiP: 4.1 ± 0.3, Table 1) and a lactic acid content of 0.47 ± 0.05% (SoP, Table 1) and 1.01 ± 0.03% (HiP, Table 1), respectively. These values are similar to those obtained for OPC enriched yoghurt that were reported by Brückner-Gühmann, Benthin and Drusch (2019) or for non-dairy fermented products based on oat (Mårtensson et al., 2001).

Table 1: Compositional properties (pH value, lactic acid content, total solids content) and textural attributes (WHC, recovery of structure, τ_0 yield point, G' at 1 Hz) of fermented, oat-based gels

Sample	pH-value	Lactic acid content	Total solids content	WHC	Recovery of structure	τ_0 yield point	G' $_{frequencysweep:1 Hz}$
	[-]	[%]	[%]	[%]	[%]	[Pa]	[Pa]
					Thixotropy test	Amplitude sweep	Frequency sweep
SoP	4.1 ± 0.3	0.47 ± 0.05*	17.8 ± 0.9*	96.2 ± 0.8*	88.8 ± 7.1*	35.5 ± 4.8*	178.7 ± 7.6*
HiP	4.2 ± 0.0	1.01 ± 0.03*	11.3 ± 0.5*	100 ± 0*	66.5 ± 8.7*	3.5 ± 0.4*	76.8 ± 28*

* significant difference in a row at $p<0.05$

3.2 Impact of total solids content on structure

The viscoelastic properties of the samples and their frequency dependency were analyzed by frequency sweeps. The results of the frequency sweeps are given in Figure 1 A. The loss factor tan δ, which represents the relation of the elastic, G', to the viscous modulus, G'', showed predominantly elastic behavior (G' > G'') over the tested range of frequencies (0.01 to 10 Hz). Consequently, both samples can be described as soft fluid gels with G' > G'' with a certain dependency of this relation on oscillation frequency based on the classification given by Fernández Farrés, Moakes, and Norton (2014). The increased storage modulus with increasing frequencies was only marginal, but tan δ increased over the frequency range. For the HiP fermented, oat-based gel, this increase was more pronounced than for the SoP gels, pointing to a stronger increase of G''. Thus, at higher frequencies more viscous properties were present in viscoelastic HiP gels. Nevertheless, the gel like structure (tan δ < 1) of both samples remained intact over the frequency range. In addition, the level of G' was higher and tan δ was lower for the SoP than for the HiP fermented, oat-based gel (Figure 1 A) indicating higher elasticity of the SoP fermented, oat-based gel with the higher total solids content (Table 1) and consequently more fat, carbohydrates, and dietary fiber. For fermented milk products containing a probiotic strain of *Lactobacillus paracasei*, it was also demonstrated previously that the total solids level positively affected the G'_{max} and $\tan\delta_{min}$ in small deformation oscillatory testing. Increasing total solids level resulted in a large increase of G'_{max} and decrease in $\tan\delta_{min}$ (Kristo, Biliaderis, & Tzanetakis, 2003).

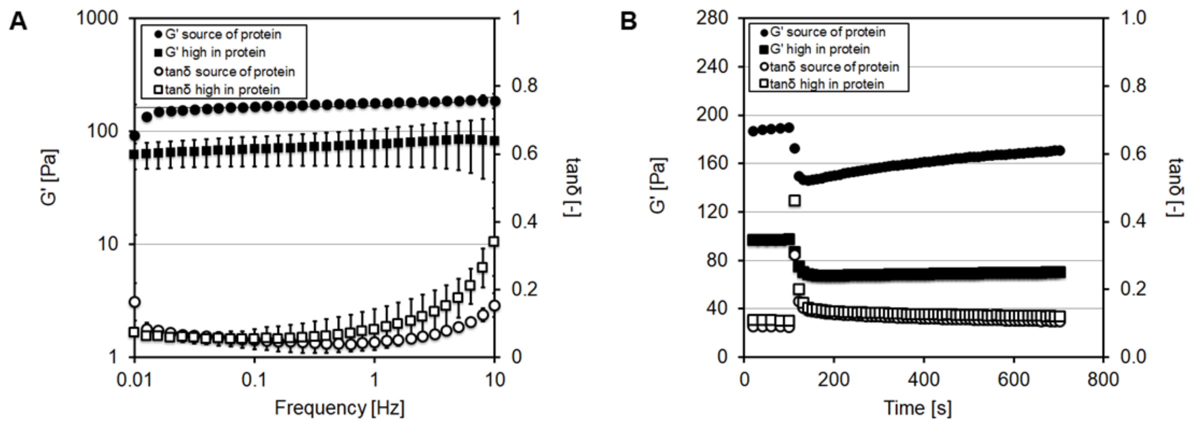

Figure 1: Frequency sweeps (deformation γ = 10^{-3}, frequencies between 0.01 to 10 Hz) (A) and thixotropy test (B) of fermented, oat-based gels

Generally, in amplitude sweeps the deformation is increased. At the intersection point, G' and G'' equate (tan δ = 1), the structure collapses. The calculated yield point τ_0 is a measure for the yield stress at which the predominately elastic behavior (G' > G'') of the fermented, oat-based gel changes to viscous behavior. The SoP sample had a significantly higher yield point τ_0 (35.5 ± 4.8 Pa, Table 1) compared to the HiP sample (3.5 ± 0.4 Pa, Table 1). Thus, less energy was needed to affect the structure of the HiP fermented, oat-based gel compared to the SoP sample. For OPC based, fermented oat-based gels it was hypothesized that the formation of a heat-induced starch-based gel dominated the structure. Generally, when heated above the gelatinization temperature, starch granules in aqueous dispersion start to swell, and amylose and amylopectin are solubilized. Once the concentrated suspensions have cooled, a gel of swollen, gelatinized starch granules dispersed in a network of amylose can be formed (Hermansson & Svegmark, 1996). It is hypothesized that the leached amylose builds up a rough macromolecular network (Djaković, Sovilj, & Milošević, 1990) by means of non-covalent interactions (Case et al., 1998), for example hydrogen bonding. In fermented, oat-based gels, besides the starch, oat protein was present in the aqueous phase. Given the poor solubility of oat protein around pH 4 (Brückner-Gühmann et al., 2019), it was presumed that protein aggregates and larger clusters were formed which did not build up a strong network. For a mixed food system of starch and protein (fermented, oat-based gel) it was very likely that swollen starch granules, protein aggregates and residual small fat droplets acted as the filler and were able to increase the rigidity (G') of the system. This dominating role of the filler and the minor role of the amylose content in the continuous phase in respect of the rheological properties of gelatinized starch dispersions was also shown by Genovese and Rao (2003).

In the SoP fermented, oat-based gel, the sample with approximately 6% higher total solids content, additional fat, fiber and carbohydrates were added to the system with the oat drink. Generally, starch pastes have been described as "naturally" reinforced polymeric materials by Carnali and Zhou (1996). In this way, the rheological properties of starch pastes were determined by the contributions and interactions of the dispersed phase (filler material for example swollen starch granules) and the dispersant (rough macromolecular network) (Carnali & Zhou, 1996; Doublier, Paton, & Llamas, 1987). It is, therefore likely, that the stability of a fermented gel based on OPC will be maintained by a starch gel rather than by a particle gel of aggregated oat protein. In line with the theory of a "naturally" reinforced polymeric material as an example of a starch paste, it is obvious that an increase in the amount of filler material, for instance additional fat, fiber or carbohydrates, would increase the rigidity of the system. In addition, an increase of water-soluble solids would decrease the amount of free, unbound water in the system which had led to less swollen starch granules with increased gel rigidity. For concentrated starch suspensions it was reported that, depending on the amount of water, particle rigidity determined the viscosity of the system (Steeneken, 1989).

Thixotropy tests were used to measure structural breakdown and its recovery based on shearing forces (Figure 1 B). For food materials, for example classic cow milk yoghurt, it is also well known that processing steps, such as mixing or pumping, lead to a partial breakdown and a time-dependent recovery of their structure (Lee & Lucey, 2010). Thixotropy tests of fermented, oat-based gels showed a decrease in structure (G') after intense shearing for both products (Figure 1 B). Shear-thinning behavior of oat starch paste was reported previously (Sikora, Kowalski, & Tomasik, 2008), suggesting that the rate of disentanglement of macromolecules by shearing was higher than that of re-entanglement. After shearing, fermented, oat-based gels were able to partially recover their initial structure. While the structure of the HiP fermented, oat-based sample recovered only to a level of 66.5 ± 8.7%, the SoP sample recovered its structure to a level of 88.8 ± 7.1% (Table 1). The thixotropic flow behavior was often a result of rupture and time-dependent reformation of bonds between molecular assemblies, usually by van der Waals forces or hydrogen bonds (DIN SPEC 91142-2:2012-09). It is, therefore, very likely that, given the higher solids content in the SoP, more junction zones were present between the particles and thus rearrangement of its microstructure was faster.

3.3 Impact of native starch on the products' structure

Water holding capacity was highest for the HiP product in which all water remained in the system after centrifugation while in the SoP sample WHC was only 96.2 ± 0.8%. Based on the sample composition (see Table 1 in Suppl. Material), the SoP fermented, oat-based gel contained 2.8% oat protein, 4.4% native oat starch from OPC and additional fat, carbohydrates and dietary fiber while the HiP fermented, oat-based gel contained 3.3% and 5.2% respectively and no additives. In contrast to the starch from the oat drink, the OPC starch had not been heat-treated before and was, therefore, in a native state. Thus, a higher amount of native starch was present in the HiP fermented, oat-based gel than in the SoP sample. Upon gelatinization, apart from a higher total solids content, only the native starch granules can swell and bind additional water. In conclusion, this higher amount (5.2%) of native starch was gelatinized and was able to bind more water than the SoP sample containing 4.4% native oat starch. It was reported previously that the higher the concentration of native starch, the more water was bound, resulting in a high water holding capacity (Hermansson & Svegmark, 1996). In addition, the fat, carbohydrates and dietary fiber, which were added with the oat drink, were not able to compensate the lower content of native starch in the SoP sample.

3.4 Consumer studies

The organoleptic properties of both samples – SoP and HiP – have been analyzed by the check-all-that-apply method (CATA) with untrained consumers. The results of the consumer tests are given in Table 2. In general, participants were able to properly describe (in sensory terms) two fermented, oat-based gels. The HiP fermented, oat-based gel was characterized as more sour and moist than SoP fermented, oat-based gel, while the SoP fermented, oat-based gel was characterized as more creamy and sweet than the HiP sample.

3.5 Correlation between compositional and rheological properties and consumer tests

Untrained consumers using CATA (Table 2) were able to significantly detect a small difference in lactic acid content (Table 1) between both samples. Consequently, the higher perceived sourness of the HiP fermented, oat-based gel (Table 2) correlates well with both the higher lactic acid content (Table 1) and the higher amount of carbohydrates in the SoP. Based on the oat drink ingredients, 6% more carbohydrates, of which 5.2% sugar, have been added to the SoP fermented, oat-based gel. Consequently, consumers described it as sweeter (Table 2).

Table 2: Proportion of sensory attributes assigned to two fermented, oat-based gels after blind tasting

Attributes*	SoP	HiP	*p*-values**
Bitter	0.108	0.176	0.127
Sour	0.402	0.598	*0.001*
Soft	0.559	0.598	0.537
Moist	0.363	0.490	*0.016*
Chewy	0.088	0.039	0.132
Adhesive/Sticky	0.196	0.147	0.336
Creamy	0.549	0.363	*0.005*
Oat	0.588	0.598	0.857
Salty	0.078	0.108	0.317
Sweet	0.245	0.010	*< 0.001*
Dry-mouthfeel	0.196	0.147	0.275
Porous	0.039	0.020	0.414
Intense-taste	0.255	0.333	0.144
Chalky	0.206	0.265	0.221
Smooth	0.451	0.578	0.053
Floury	0.490	0.480	0.873

*Cochran's Q test for each attribute.

**p-values in italics differ significantly at least at $p < 0.05$.

In addition, consumers described the HiP fermented, oat-based gel as more moist (Table 2) which correlated well with the lower level of total solids content (Table 1), the reduced ability of the product to recover its structure (G') after shearing (200 s^{-1} for 2 min) (Table 1, Figure 1,) and with the lower value of the elastic modulus G', which was taken from the frequency sweeps at 1 Hz (Table 1). Consequently, the elastic modulus G', which was taken from the frequency sweeps at 1 Hz (Table 1), increased with rising total solids content (higher level for the SoP sample, Table 1). The relationship between total solids content and perceived firmness and viscosity was reported previously for fermented dairy products: the lower the total solids content, the lower the firmness and viscosity (Biliaderis, Khan, & Blank, 1992; Gastaldi, Lagaude, Marchesseau, & Tarodo de la Fuente, 1997; Tamime & Robinson, 2007).

In a recent review by Dickinson (2018) he stated that there is a close connection between creaminess and perceived thickness, smoothness, mouth-coating and dairy flavor. In addition, previous experiments have shown that creaminess was linked to the product's apparent viscosity: it increased by a higher viscosity (Akhtar, Stenzel, Murray, & Dickinson, 2005; Chojnicka-Paszun, de Jongh, & de Kruif, 2012; Kokini, 1987; Moore, Langle, Wilde, Filler, & Mela, 1998). Consequently, consumer tests resulted in higher perceived creaminess for the SoP fermented, oat-based gel which had a higher total solids content, than for the HiP (Table 2). In addition, the SoP had a significantly ($p < 0.05$) higher yield point τ_0 determined by amplitude sweeps (Table 1). If we assume that the fermented, oat-based gels consisted of "naturally" reinforced polymeric material, the structural components starch, protein aggregates, fat, fiber and carbohydrates might be able to generate a creamy impression. This mimicking behavior of milk fat droplets by structural components such as starch and protein aggregates and the creation of creaminess (smoothness and thickness) impressions in the absence of milk fat was reported previously (Dickinson, 2018).

To sum up, compositional and rheological properties correlated well with the perceptions of untrained consumers using CATA for the sensory terms – sour, moist, creamy and sweet. The HiP sample containing fewer carbohydrates but more lactic acid (Table 1) was perceived as more sour while the SoP was deemed to be sweeter (Table 2). The significantly ($p < 0.05$) reduced ability to recover its structure (G') after shearing (200 s^{-1} for 2 min) and the lower value of the elastic modulus G', which was taken from the frequency sweeps at 1 Hz, (Table 1), correlated with the lower total solids content and consequently higher perceived moisture of the HiP (Table 2). The significantly ($p < 0.05$) higher yield point τ_0 of the SoP sample (Table 1) correlated well with the higher perceived creaminess (Table 2).

3.6 Identification of key drivers of liking

The results of the consumer tests were used to identify the key drivers of liking. Principal Coordinates Analysis was, therefore, applied to the sensory attributes' correlation coefficients and overall liking (Figure 2). The first two dimensions explain 65.5% of the variation and overall liking is mainly related to the sensory attributes – sweet, moist, soft, and smooth.

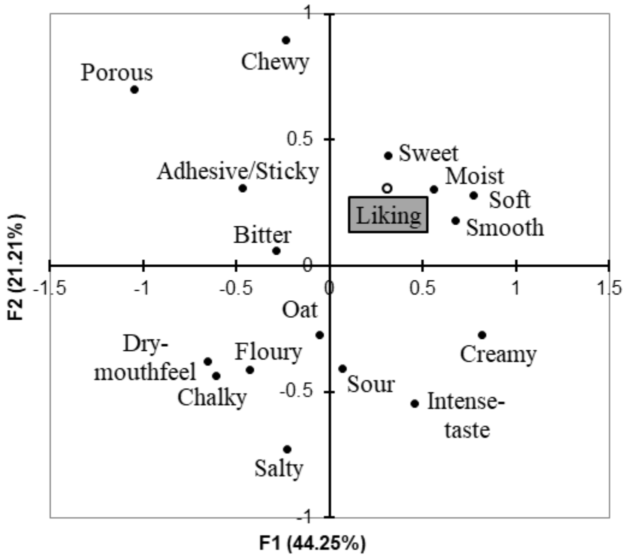

Figure 2. Principal Coordinates Analysis of the sensory descriptors and overall liking.

Further, a penalty analysis was performed in order to gain an understanding of which sensory attributes increase or decrease the overall liking of the two products or which presence or absence of sensory attribute affects the overall liking of the two products (Table 3). As shown in Table 3, the sensory attribute, creamy, increases the overall liking of the products by 1.80 points, while the attributes – sour, chalky and floury – decrease the overall liking of the products by -1.36, -1.33, and -0.88, respectively. Thus, creamy attributes in the oat-protein enriched fermented gel generate added value, while sour, chalky and floury attributes are not desired and should be further attuned to consumer tastes.

Table 3: Comparison of sensory attributes and its impact on overall liking for the two variants after blind-tasting.

Variable	Level	Freq.	%	Mean (Liking)	Mean impact	Standardized difference	p-value
Bitter	Absent	175	85.78%	3.971			
	Present	29	14.22%	3.241	-0.730		
Sour	Absent	102	50.00%	4.549			
	Present	102	50.00%	3.186	-1.363	-4.271	*< 0.001*
Soft	Absent	86	42.16%	3.535			
	Present	118	57.84%	4.110	0.575	1.718	0.087
Moist	Absent	117	57.35%	3.769			
	Present	87	42.65%	4.000	0.231	0.686	0.494
Chewy	Absent	191	93.63%	3.921			
	Present	13	6.37%	3.077	-0.845		
Adhesive/Sticky	Absent	169	82.84%	4.041			
	Present	35	17.16%	3.029	-1.013		
Creamy	Absent	111	54.41%	3.045			
	Present	93	45.59%	4.849	1.804	5.832	*< 0.001*
Oat	Absent	83	40.69%	4.133			
	Present	121	59.31%	3.686	-0.447	-1.323	0.187
Salty	Absent	185	90.69%	3.924			
	Present	19	9.31%	3.316	-0.609		
Sweet	Absent	178	87.25%	3.674			
	Present	26	12.75%	5.192	1.518		
Dry-mouthfeel	Absent	169	82.84%	4.000			
	Present	35	17.16%	3.229	-0.771		
Porous	Absent	198	97.06%	3.848			
	Present	6	2.94%	4.500	0.652		
Intense-taste	Absent	144	70.59%	3.875			
	Present	60	29.41%	3.850	-0.025	-0.068	0.946
Chalky	Absent	156	76.47%	4.179			
	Present	48	23.53%	2.854	-1.325	-3.474	*0.001*
Smooth	Absent	99	48.53%	3.616			
	Present	105	51.47%	4.105	0.489	1.474	0.142
Floury	Absent	105	51.47%	4.295			
	Present	99	48.53%	3.414	-0.881	-2.691	*0.008*

**p* – values in italics all significant at 0.05.

Based on the correlations between the rheological measurements, compositional parameters (lactic acid content, total solids content) and consumer tests, the identified key drivers – sweet, moist, soft, and smooth – can be directly controlled and used to design a product with the desired properties.

3.7 Importance of information disclosure

According to the EU regulation on nutrition claims (Regulation (EC) No 1924/2006, amended by Regulation (EU) No 1047/2012), the two protein related claims – “source of protein” or “high in protein” – can be made on food packaging. In this study, information about oat-protein enrichment was shown to the consumers before starting the product evaluations. When comparing consumer acceptance of the products in the blind tasting condition to the information condition, significant differences were observed in favor of the informed condition for all the variables (i.e. overall liking, visual appearance, flavor, texture, and overall quality, all $p_s < 0.05$ from t-tests). This points to higher consumer acceptance of protein enriched fermented, oat-based gels with the addition of information (Figure 3).

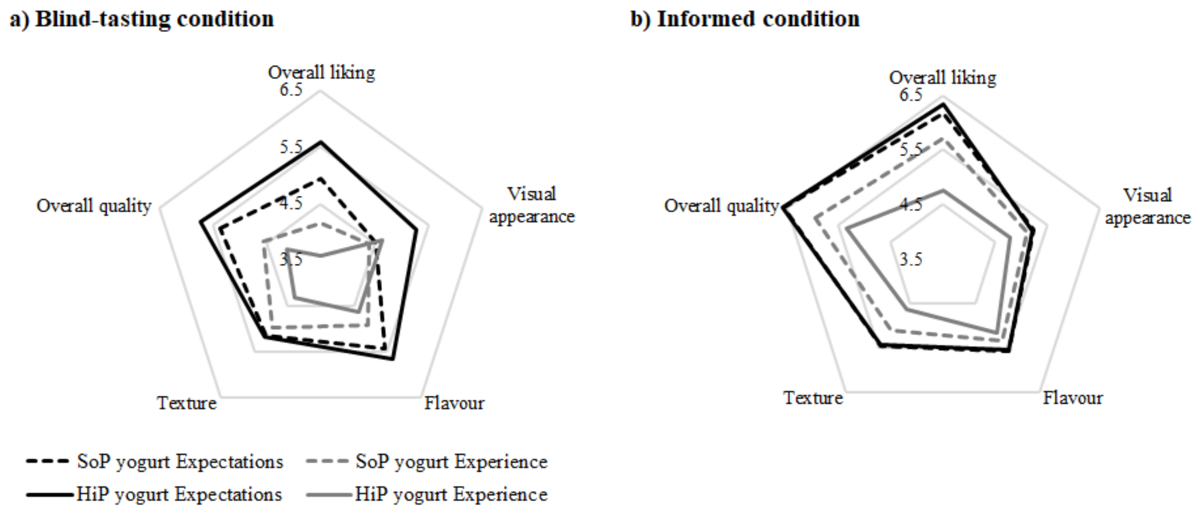

Figure 3. Mean acceptability values per product under blind-tasting and informed condition in expectation and experience phase.

Furthermore, the correlation between consumer acceptance in terms of purchase intention after consuming the product and the two conditions – blind tasting versus information condition significant – shows a positive correlation when information is provided (r = 0.253, $p < 0.05$) and a negative correlation when no information is provided (blind tasting, r = -0.253, $p < 0.05$). There are very few studies on how consumers view plant protein enriched products and the impact of health claims on purchase intention (Banovic et al., 2018). Nevertheless, it was demonstrated previously that the willingness to accept and buy a product is complex and is, therefore, dependent on various properties linked to the consumers themselves (familiarity, knowledge of nutrition, functionality and personal relevance) or to the product (category, functionality, taste, claims) (Wills et al., 2012). It has already been demonstrated for yoghurt that it benefits considerably from health claims (van Kleef, van Trijp, & Luning, 2005). To change eating habits, lactic acid fermented, non-dairy, oat-based gels could also profit from information disclosure.

4. Conclusion

Diets high in plant-based proteins are increasingly recommended for health and environmental reasons. We were able to find evidence that lactic acid fermented, oat-based gels are a good carrier for oat protein enrichment. In addition, the lactic-acid fermented oat-based gels could claim to be “source of protein” (SoP) or “high in protein” (HiP) products. Both samples were characterized as soft fluid gels. While the total solids content governed rheological properties, native starch determined the water holding capacity (WHC) of the samples. In addition, this study has shown that oat protein in general and oat protein concentrate (OPC) in particular can serve as functional ingredients in lactic acid fermented, oat-based gels with good overall textural properties. As discussed in literature, consumer acceptance and purchase intention are complex. We found measurable, objective, sensory attributes like sweet, moist, soft, and smooth, which influenced product acceptance as well as the more extrinsic attribute information disclosure which could help to change consumer eating habits. As consumption patterns only change slowly, future work should continue with this interdisciplinary approach of combining consumer science and food technology. By directly integrating consumers' perceptions of plant-protein enriched products the food industry can more easily generate products with higher added value.

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Supplementary material

Table 1: Ingredients, protein content and percentage of energy from protein of fermented, oat-based gels

SoP							
Ingredient	Amount of ingredient in recipe [g]	Calories of ingredients[a] [kcal/100 g]	Amount of energy[b] [kcal]	Protein content of ingredient [%]	Amount of protein in portion[c] [g]	Calories from protein[d] [kcal]	Percentage of energy from protein[e] [%]
OPC	216	365	788.4	28.3	61.1	244.4	31.0
Oat drink	2000	39	780	0.6	12	48	6.1
Sugar	20	400	80	0			
Sum	2236		1648.4		73.1	292.4	**17.7**
HiP							
Ingredient	Amount of ingredient in recipe [g]	Calories of ingredients [kcal/100 g]	Amount of energy [kcal]	Protein content of ingredient [%]	Amount of protein in portion [g]	Calories from protein* [kcal]	Percentage of energy from protein [%]
OPC	258.9	365	944.9	28.3	73.3	293.1	31.0
Water	2000	0	0	0		0	
Sugar	20	400	80	0		0	
Sum	2278.9		1024.9		73.3	293.1	**28.6**

[a] According to Livesey (2001) 1 g of fat, protein, carbohydrates and fiber provide 4, 9, 4 and 2 kcal, respectively. Based on these basic assumptions, the nutritional value (kcal/100 g) of OPC was calculated as 365 kcal with 45 kcal provided by 5 g fat, 112 kcal provided by 28 g protein and 208 kcal provided by 52 g total carbohydrates. The nutritional value of the oat drink was given by the supplier.

[b] The amount of energy refers to the energy of each ingredient in the recipe. For example, 216 g OPC have an energy of 2.6*365 = 788.4 kcal

[c] For example: $Amount\ of\ protein\ in\ portion = 216\ g\ \cdot 28.3\% = 61.1\ g$

[d] 1 g protein provides 4 kcal, $Calories\ from\ protein =\ 4\ kcal\ \cdot amount\ of\ protein\ in\ portion$

[e] $Percentage\ of\ energy\ from\ protein = \frac{calories\ from\ protein}{amount\ of\ energy}$

References

Akhtar, M., Stenzel, J., Murray, B. S., & Dickinson, E. (2005). Factors affecting the perception of creaminess of oil-in-water emulsions. *Food Hydrocolloids*, *19*(3), 521–526. http://doi.org/10.1016/j.foodhyd.2004.10.017

Ares, G., Barreiro, C., Deliza, R., Giménez, A., & Gámbaro, A. (2010). Application of a check-all-that-apply question to the development of chocolate milk desserts. *Journal of Sensory Studies*, *25*, 67–86. http://doi.org/10.1111/j.1745-459X.2010.00290.x

Ares, G., Dauber, C., Fernández, E., Giménez, A., & Varela, P. (2014). Penalty analysis based on CATA questions to identify drivers of liking and directions for product reformulation. *Food Quality and Preference*, *32*, 65–76. http://doi.org/10.1016/j.foodqual.2013.05.014

Banović, M., Fontes, M. A., Barreira, M. M., & Grunert, K. G. (2012). Impact of Product Familiarity on Beef Quality Perception. *Agribusiness*, *28*(2), 157–172. http://doi.org/10.1002/agr.21290

Banović, M., Krystallis, A., Guerrero, L., & Reinders, M. J. (2016). Consumers as co-creators of new product ideas: An application of projective and creative research techniques. *Food Research International*, *87*, 211–223. http://doi.org/10.1016/j.foodres.2016.07.010

Banovic, M., Lähteenmäki, L., Arvola, A., Pennanen, K., Duta, D. E., Brückner-Gühmann, M., & Grunert, K. G. (2018). Foods with increased protein content: A qualitative study on European consumer preferences and perceptions. *Appetite*, *125*, 233–243. http://doi.org/10.1016/j.appet.2018.01.034

Bedani, R., Vieira, A. D. S., Rossi, E. A., & Saad, S. M. I. (2014). Tropical fruit pulps decreased probiotic survival to invitro gastrointestinal stress in synbiotic soy yoghurt with okara during storage. *LWT - Food Science and Technology*, *55*(2), 436–443. http://doi.org/10.1016/j.lwt.2013.10.015

Biliaderis, C. G., Khan, M. M., & Blank, G. (1992). Rheological and sensory properties of yogurt from skim milk and ultrafiltered retentates. *International Dairy Journal*, *2*(5), 311–323. http://doi.org/10.1016/0958-6946(92)90035-K

Blandino, A., Al-Aseeri, M. E., Pandiella, S. S., Cantero, D., & Webb, C. (2003). Cereal-based fermented foods and beverages. *Food Research International*, *36*, 527–543. http://doi.org/10.1016/S0963-9969(03)00009-7

Brückner-Gühmann, M., Benthin, A., & Drusch, S. (2019). Enrichment of yoghurt with oat protein fractions: Structure formation, textural properties and sensory evaluation. *Food Hydrocolloids*, *86*, 146–153. http://doi.org/10.1016/j.foodhyd.2018.03.019

Buono, M. a., Setser, C., Erickson, L. E., & Fung, D. Y. C. (1990). Soymilk Yogurt: Sensory Evaluation and Chemical Measurement. *Journal of Food Science*, *55*(2), 528–531.

Carnali, J. O., & Zhou, Y. (1996). An examination of the composite model for starch gels. *Journal of Rheology*, *40*(2), 221–234. http://doi.org/10.1122/1.550739

Case, S. E., Capitani, T., Whaley, J. K., Shi, Y. C., Trzasko, P., Jeffcoat, R., & Goldfarb, H.

B. (1998). Physical properties and gelation behavior of a low-amylopectin maize starch and other high-amylose maize starches. *Journal of Cereal Science*, *27*(3), 301–314. http://doi.org/10.1006/jcrs.1997.0164

Chojnicka-Paszun, A., de Jongh, H. H. J., & de Kruif, C. G. (2012). Sensory perception and lubrication properties of milk: Influence of fat content. *International Dairy Journal*, *26*(1), 15–22. http://doi.org/10.1016/j.idairyj.2012.04.003

Claret, A., Guerrero, L., Gartzia, I., Garcia-Quiroga, M., & Ginés, R. (2016). Does information affect consumer liking of farmed and wild fish? *Aquaculture*, *454*, 157–162. http://doi.org/10.1016/j.aquaculture.2015.12.024

Dickinson, E. (2018). On the road to understanding and control of creaminess perception in food colloids. *Food Hydrocolloids*, *77*, 372–385. http://doi.org/10.1016/j.foodhyd.2017.10.014

DIN EN IOS 8589:2014-10 Sensorische Analyse – Allgemeiner Leitfaden für die Gestaltung von Prüfräumen. (n.d.). *DIN Deutsches Institut Für Normung e. V*.

DIN SPEC 91142-2:2012-09 Moderne rheologische Prüfverfahren – Teil 2: Thixotropie – Bestimmung der zeitabhängigen Strukturänderung – Grundlagen und Ringversuch. (2012). *DIN Deutsches Institut Für Normung e. V*, (September).

DIN-Fachbericht 143:2005-04 Moderne rheologische Prüfverfahren – Teil 1: Bestimmung der Fließgrenze – Grundlagen und Ringversuch. (2005). *DIN Deutsches Institut Für Normung e.V.*

Djaković, L. J., Sovilj, V., & Milošević, S. (1990). Rheological Behaviour of Thixotropic Starch and Gelatin Gels. *Starch - Stärke*, *42*(10), 380–385. http://doi.org/10.1002/star.19900421004

Donkor, O. N., Henriksson, A., Vasiljevic, T., & Shah, N. P. (2007). α-Galactosidase and proteolytic activities of selected probiotic and dairy cultures in fermented soymilk. *Food Chemistry*, *104*(1), 10–20. http://doi.org/10.1016/j.foodchem.2006.10.065

Doublier, J.-L., Paton, D., & Llamas, G. (1987). A rheological investigation of oat starch pastes. *Cereal Chemistry*.

Fernández Farrés, I., Moakes, R. J. A., & Norton, I. T. (2014). Designing biopolymer fluid gels: A microstructural approach. *Food Hydrocolloids*, *42*(P3), 362–372. http://doi.org/10.1016/j.foodhyd.2014.03.014

Gastaldi, E., Lagaude, A., Marchesseau, S., & Tarodo de la Fuente, B. (1997). Acid Milk Gel Formation as Affected by Total Solids Content. *Journal of Food Science*, *62*(4), 671–687. http://doi.org/10.1111/j.1365-2621.1997.tb15432.x

Genovese, D. B., & Rao, M. A. (2003). Role of starch granule characteristics (volume fraction, rigidity, and fractal dimension) on rheology of starch dispersions with and without amylose. *Cereal Chemistry*, *80*(3), 350–355. http://doi.org/10.1094/CCHEM.2003.80.3.350

González, A. D., Frostell, B., & Carlsson-Kanyama, A. (2011). Protein efficiency per unit energy and per unit greenhouse gas emissions: Potential contribution of diet choices to climate change mitigation. *Food Policy*, *36*(5), 562–570. http://doi.org/10.1016/j.foodpol.2011.07.003

Grasso, S., Monahan, F. J., Hutchings, S. C., & Brunton, N. P. (2017). The effect of health claim information disclosure on the sensory characteristics of plant sterol-enriched turkey as assessed using the Check-All-That-Apply (CATA) methodology. *Food Quality and Preference*, *57*, 69–78. http://doi.org/10.1016/j.foodqual.2016.11.013

Guzman-Gonzalez, M., Morais, F., Ramos, M., & Amigo, L. (1999). Influence of skimmed milk concentrate replacement by dry dairy products in a low fat set-type yoghurt model system. I: Use of whey protein concentrates, milk protein concentrates and skimmed milk powder. *Journal of the Science of Food and Agriculture*, *79*(8), 1117–1122. http://doi.org/10.1002/(SICI)1097-0010(199906)79:8<1117::AID-JSFA335>3.0.CO;2-F

Hermansson, A. M., & Svegmark, K. (1996). Developments in the understanding of starch functionality. *Trends in Food Science and Technology*, *7*(11), 345–353. http://doi.org/10.1016/S0924-2244(96)10036-4

Juster, F. T. (1966). Consumer Buying Intentions and Purchase Probability: An Experiment in Survey Design. *Journal of the American Statistical Association*, *61*(315), 658–696. http://doi.org/10.1080/01621459.1966.10480897

van Kleef, E., van Trijp, H. C. M., & Luning, P. (2005). Functional foods: health claim-food product compatibility and the impact of health claim framing on consumer evaluation. *Appetite*, *44*(3), 299–308. http://doi.org/10.1016/j.appet.2005.01.009

Kokini, J. L. (1987). The physical basis of liquid food texture and texture - taste interactions. *Journal of Food Engineering*, *6*, 51–81.

Kristo, E., Biliaderis, C. G., & Tzanetakis, N. (2003). Modelling of rheological, microbiological and acidification properties of a fermented milk product containing a probiotic strain of Lactobacillus paracasei. *International Dairy Journal*, *13*(7), 517–528. http://doi.org/10.1016/S0958-6946(03)00074-8

Larsson, S. C., & Wolk, A. (2012). Red and processed meat consumption and risk of pancreatic cancer: Meta-analysis of prospective studies. *British Journal of Cancer*, *106*(3), 603–607. http://doi.org/10.1038/bjc.2011.585

Lee, W. J., & Lucey, J. a. (2010). Formation and physical properties of yogurt. *Asian-Australasian Journal of Animal Sciences*, *23*(9), 1127–1136. http://doi.org/10.5713/ajas.2010.r.05

Mäkinen, O. E., Sozer, N., Ercili-Cura, D., & Poutanen, K. (2017). Protein From Oat: Structure, Processes, Functionality, And Nutrition. In S. R. Nadathur, J. Wanasundara, & L. Scanlin (Eds.), *Sustainable Protein Sources* (1st ed., pp. 105–119). Academic Press Inc. (London) Limited.

Mårtensson, O., Andersson, C., Andersson, K., Öste, R., & Holst, O. (2001). Formulation of an oat-based fermented product and its comparison with yoghurt. *Journal of the Science of Food and Agriculture*, *81*(14), 1314–1321. http://doi.org/10.1002/jsfa.947

Meyners, M., Castura, J. C., & Carr, B. T. (2013). Existing and new approaches for the analysis of CATA data. *Food Quality and Preference*, *30*(2), 309–319. http://doi.org/10.1016/j.foodqual.2013.06.010

Moore, P. B., Langle, K., Wilde, P. J., Filler, A., & Mela, D. J. (1998). Effect of Emulsifier Type on Sensory Properties of Oil-in-Water Emulsions. *Journal of the Science of Food and Agriculture*, *76*, 469–476.

Pohjolainen, P., Vinnari, M., & Jokinen, P. (2015). Consumers' perceived barriers to following a plant-based diet. *British Food Journal*, *117*(3), 1150–1167. http://doi.org/10.1108/BFJ-09-2013-0252

Rao, D. R., Pulusani, S. R., & Chawan, C. B. (1988). Preparation of a yogurt-like product from cowpeas and mung beans. *International Journal of Food Science & Technology*, *23*(2), 195–198. http://doi.org/10.1111/j.1365-2621.1988.tb00567.x

Rasane, P., Jha, A., Sabikhi, L., Kumar, A., & Unnikrishnan, V. S. (2013). Nutritional advantages of oats and opportunities for its processing as value added foods - a review. *Journal of Food Science and Technology*, *52*(2), 662–675. http://doi.org/10.1007/s13197-013-1072-1

Regulation (EC) No 1047/2012 amending Regulation (EC) No 1924/2006 with regard to the list of nutrition claims. (2012). *The European Parliament and the Council of the European Union*.

Regulation (EC) No 1924/2006 on nutrition and health claims made on foods. (2006). *The European Parliament and the Council of the European Union*.

Rouhani, M. H., Salehi-Abargouei, A., Surkan, P. J., & Azadbakht, L. (2014). Is there a relationship between red or processed meat intake and obesity? A systematic review and meta-analysis of observational studies. *Obesity Reviews*, *15*(9), 740–748. http://doi.org/10.1111/obr.12172

Siegrist, M., Stampfli, N., & Kastenholz, H. (2008). Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. *Appetite*, *51*(3), 526–529. http://doi.org/10.1016/j.appet.2008.04.003

Sikora, M., Kowalski, S., & Tomasik, P. (2008). Binary hydrocolloids from starches and xanthan gum. *Food Hydrocolloids*, *22*(5), 943–952. http://doi.org/10.1016/j.foodhyd.2007.05.007

Steeneken, P. A. M. (1989). Rheological properties of aqueous suspensions of swollen starch granules. *Carbohydrate Polymers*, *11*(1), 23–42. http://doi.org/10.1016/0144-8617(89)90041-6

Tamime, A. Y., & Robinson, R. K. (2007). *Tamime and Robinson's Yoghurt: Science and Technology: Third Edition*. *Tamime and Robinson's Yoghurt: Science and Technology: Third Edition*. http://doi.org/10.1533/9781845692612.348

Wang, Y., & Beydoun, M. A. (2009). Meat consumption is associated with obesity and central obesity among US adults. *International Journal of Obesity*, *33*(6), 621–628. http://doi.org/10.1038/ijo.2009.45

Wills, J. M., Storcksdieck genannt Bonsmann, S., Kolka, M., & Grunert, K. G. (2012). European consumers and health claims: attitudes, understanding and purchasing behaviour. *Proceedings of the Nutrition Society*, *71*(02), 229–236. http://doi.org/10.1017/S0029665112000043