Lactic acid bacteria fermentations in oat-based suspensions

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Formulation of an oat-based fermented product and its comparison with yoghurt

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Abstract: In an attempt to develop a fermented, non-dairy product based on oats, a new kind of oat base, Adavena® M40, was fermented with two different yoghurt cultures. Adavena® M40 is a concentrated liquid (with a dry matter content of 16 or 18%) derived entirely from oats, with maltose as the main carbohydrate source and an intact β-glucan content. The oat base was heat treated for 5 min at 85 °C prior to inoculation. Additives in the form of stabiliser, fat and flavours were used. Texture, syneresis, colour and sensory parameters were evaluated. Yoghurt was used as a control. The final product had an acidity and viscosity similar to those of yoghurt. Addition of xanthan gum (0.03% w/v) improved the texture and overall appearance of the product. The product had the same texture as yoghurt but showed less syneresis. The mixture was less white than the control. The oat-based, yoghurt-like product showed high acceptability in terms of acidity, texture and overall appearance. The addition of flavours resulted in a higher acceptance of the final products by the panellists. The β-glucan content was still high after the fermentation process. The results indicated the potential for a new, fermentable, oat-based product with high acceptance and a high final β-glucan content.

Keywords: Adavena®; oats; non-dairy; lactic acid bacteria

INTRODUCTION

There is a need to increase the consumption of oat-based products, as the well-documented, positive effect of a diet rich in oat bran and dietary fibres from oats on blood cholesterol levels indicates that an increased intake of oat-based products would be beneficial.[1,2] High serum cholesterol concentration is among the factors associated with an increased risk of ischaemic heart disease.[3] The low consumption of products based on oats is due mainly to the lack of acceptable and suitable food products containing soluble fibre at appropriate levels.[4] To increase interest in oats as a base for new, functional food products, the use of a fermentation process in combination with a new kind of tailored oat base, rich in dietary fibre, could provide new foods such as yoghurt-like products based on oats. A new kind of food base derived from oats, Adavena® M40 (Ceba AB, Lund, Sweden), was used in developing a new type of non-dairy, yoghurt-like product. The oat base used is made entirely of oats and water by a patented enzymatic process.[5] One application of this oat base to date is as a non-dairy milk substitute, Mill Milk™ (Ceba AB, Lund, Sweden), which has been reported to have high acceptance among consumers and a cholesterol-lowering effect.[6,7] A previous study has also shown that this product is suitable as a substrate for various kinds of lactic acid bacteria.[8] Other non-dairy, yoghurt-like products have been developed from rice,[9] soya and other legumes[10,11] and cereals.[4,12] The general problem has been to obtain a product with an appearance, texture and sensory quality similar to those of ordinary yoghurt.[11] The main objection in sensory evaluations of these products has been the beany flavour of the final product.[11,13] Investigations have also been carried out using mixed substrates as the fermentation base for the product or, with the addition of different components of milk, such as lactose, whey and casein, to obtain appropriate fermentation characteristics.[12,14]

The aim of the present study was to investigate the use of the new oat base as the main substrate for yoghurt cultures. Such knowledge will facilitate development of new, fermented oat-based products with good nutritional and physical properties combined with high consumer acceptance.

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EXPERIMENTAL

Substrate and fermentations

The oat base Adavena® M40 used was made from rolled oats and water by an enzymatic method described earlier.[5] Adavena® M40 oat base concentrate (20% dry matter) was kindly provided in frozen form by Ceba AB (Lund, Sweden). It was analysed for protein, fat, various carbohydrates, dietary fibre and various vitamins and minerals by an authorised laboratory (AnalyCen Nordic AB, Kristianstad, Sweden) (Table 1). The oat base was diluted to a final dry matter content of 18 or 16%, heat treated at 85 °C with continuous stirring for 5 min and subsequently cooled to fermentation temperature. Two commercial yoghurt cultures, V2 and ABT, were used for the preparation of non-dairy yoghurts. V2 is a 1:1 mixture of *Lactobacillus delbrueckii* subsp *bulgaricus* and *Streptococcus salivarius* subsp *thermophilus* (Visby Tønder A/S, Tønder, Denmark). It was chosen because it is a common starter culture in yoghurt products in Sweden. ABT is a mixture of *L acidophilus, S salivarius* subsp *thermophilus* and *Bifidobacterium* spp (Chr Hansen A/S, Hørsholm, Denmark). It was chosen for its ability to ferment maltose, which is the main carbohydrate source in the oat base that was used. To evaluate the two cultures' ability to ferment the oat base in terms of pH reduction and aroma formation, the fermentations were performed over a defined period of time, 16 h at 43 °C. A 0.02% portion of the starter culture was used as inoculum. The yoghurt control (Yoggi®), a commercial product fermented with the V2 culture, was obtained from Skånemejerier (Malmö, Sweden). The fermented, non-dairy yoghurt control (Sevea®), which is a fermented mixture of both soy and oats, was purchased from Vitapole/Danone (Paris, France).

Table 1. Chemical composition of the M40 medium (20% concentrate)

Component	*Amount (kg^{-1})*
Protein (g)	22
Fat (g)	15
Maltose (g)	85
Maltodextrin (g)	55
Total fibre (g)	16
β-Glucan (g)	8
α-Tocopherol (mg)	2
Thiamin (mg)	0.8
Riboflavin (μg)	192
Niacin (mg)	2
Folic acid (μg)	66
Pyridoxine (mg)	0.2
Iron (mg)	2
Magnesium (mg)	94
Manganese (mg)	2
Phosphorus (mg)	540
Sodium (mg)	220
Zinc (mg)	2

Additives

Xanthan gum (CP-Kelco, Copenhagen, Denmark) was added to a final concentration of 0.03%. The different flavour components, strawberry or mixed berry jam (Hafi AB, Getinge, Sweden), were added to a concentration of 12% in the final products. Akoblend NS (Karlshamns AB, Karlshamn, Sweden), a vegetable fat suitable for dairy applications as partial or total replacement of milk fat, was added to give a final fat content of 1.8%.

The xanthan gum and fat were added before heat treatment, while all flavours were added after fermentation.

Analyses

The survival of the yoghurt cultures was assessed as viable counts by serial dilution in peptone water (1 g peptone, 8 g NaCl, 1000 ml water) and spreading on plates using differential media, MRS[15] agar (Merck, Darmstadt, Germany) selective for *Lactobacillus* and M17[16] agar (Merck) selective for *Streptococcus*. To measure the change in microbial survival in the product during storage, samples were taken out and spread on agar plates every fifth day throughout the 20 days of storage. The plates were incubated in anaerobic jars (85% N_2, 10% H_2, 5% CO_2) for 48 h at 37 °C.

Lactic acid, reported as acidity, was estimated by titrating 10 ml of each sample with 0.1 M NaOH using phenolphthalein as indicator.[17] Viscosity was measured using a Bohlin Visco 88 BV, cylinder C30, 1207 s^{-1} (Bohlin Reologi, Lund, Sweden) and expressed in mPa s. Measurements were made for 2 min at 10 and 25 °C. The texture was measured using an Instron 4442 (Instron Ltd, Buckinghamshire, UK). A 25 ml portion of the sample was transferred to a Petri dish. A probe with a diameter of 3.8 cm was put on the surface of the sample and lifted up at a speed of 100 cm min^{-1}. When the product lost contact with the probe, the measurement was terminated. The measurements were done in triplicate and at ambient temperature. Texture together with viscosity was taken as a parameter for the consistency of the product.

Water activity was determined using a Rotronic instrument (Rotronic AG, Rotweil, Germany). Dry matter was determined by drying samples of 1 g in a drying chamber for 3 h at 102 °C. The dry samples were cooled to ambient temperature in a desiccator before weighing.

To investigate susceptibility to syneresis, samples of 40 g were centrifuged for 10 min using various centrifugation rates ($35 \times g$, $145 \times g$, $325 \times g$, $580 \times g$, $910 \times g$ and $1310 \times g$) at 4 °C. After centrifugation the supernatant was drained for 1 min and the collected volume was measured.

Maltose was determined by enzymatic degradation and measured on a spectrophotometer (Pharmacia, Uppsala, Sweden) at a wavelength of 385 nm.[18] Fat was determined using the Schmid–Bondzynski–Ratslaff method.[19] The content of β-glucans in the

samples was measured after enzymatic degradation with lichenase and β-glucosidase.[20]

Colour analysis was performed using a Minolta Colour Instrument with the measuring head CR-310. The sample (25 ml) was transferred to a cuvette and left for 1 min before putting it inside the measuring head.

All values reported are the mean of three measurements.

Sensory evaluation

A semi-trained panel of 13 members was engaged for both the intensity and preference evaluations, which were performed on different occasions. The members were selected based on their threshold to basic flavours and were trained to score preference solutions using numerical intensity scales.

Intensity scales were defined using 9 cm lines for sweetness, acidity, consistency, oat flavour, mouthfeel, appearance and overall acceptability. Reference samples were used for setting the intensity scales and for panel training. For acidity reference, 1 and 2% sucrose were added to commercial, plain milk yoghurt, corresponding to 4.5 and 1 respectively on the scale, with 0.2% of added citric acid corresponding to 9. Evaporated Adavena(R) M40 liquid oat base was used for the oat flavour references, in concentrations of 10, 15 and 20% in tap water, corresponding to 1.5, 4.5 and 9 respectively on the scale. Yoghurt Naturell (Skånemejerier, Malmö, Sweden) with added sucrose at 2, 5 and 18% levels was used for the sweetness scale, corresponding to 1, 4.5 and 9 respectively on the scale. For texture and mouthfeel, evaporated Adavena(R) M40 liquid oat base, a low-fat milk yoghurt, Vitalinea(R) (Danone Scandinavia, Malmö, Sweden), and a soy dessert, Deluxe Soyage(R) (grano Vita, London, UK), were used as references, corresponding to 1, 4.5 and 9 respectively on the scale. The references were set to an optimal score of 4.5 for texture/viscosity (orally described as consistency), sweetness and acidity, whereas for appearance, mouthfeel and overall acceptability the reference score was 9. No optimal score was set for oat flavour, as it was evaluated mainly to investigate how prominent the flavour was considered to be; neither was any optimal score set for appearance.

Ranking for preference was conducted by noting the most desirable product according to the panellists. The panellists were asked to number the products according to their preference from 1 to 9 using the same sensory qualifications as in the intensity evaluation, except for oat flavour which was excluded in this test. The closer the rank sum was to the highest reference score (54.0), the higher was the overall preference for the product.

All samples were coded with three digits and randomly presented to panellists at the same time, with a volume of 100 ml in every container on each occasion. The containers were white plastic cups used for commercially distributed yoghurt in Sweden. The serving temperature was 6 °C in a room with fluorescent illumination. No booths were used during the evaluation. All samples were evaluated during one session. Two treatments of each product were performed during a session. The results of the sensory evaluations were reported as mean values of two sensory sessions with standard deviations.

Statistical analyses

Results concerning the different products, including treatment for intensity scales, were analysed by paired *t*-tests. Significance of ranking for preference tests was analysed using Kramer's table.[21] Principal component analysis of the sensory evaluation data was performed with The Unscrambler.[22]

RESULTS

Fermentation

Both yoghurt cultures gave a final pH value below 4.5. The ABT culture gave stronger acid formation and a final pH below 4.0. There was no difference between the mixtures with different dry matter contents in terms of final pH after fermentation. Final pH, viscosity, texture, lactic acid production and consumption of the main carbohydrate, maltose, are listed in Table 2. Fig 1 shows the fermentation profile of the two starter cultures, ABT and V2. The survival of the V2 culture in the plain product was measured over 20

Table 2. Viscosity, texture, pH, titratable acidity, β-glucan content and maltose content after fermentation for 16 h of the M40 substrate with different dry matter contents (16 and 18%) in comparison with a yoghurt control

Yoghurt culture	*Dry matter (%)*	*Viscosity* (mPa s)*	*Texture† (cm)*	*pH‡*	*Titratable acidity (%)*	*Maltose (%)*	*β-Glucan (%)*
ABT	16	78^{a}	1.7^{c}	3.9^{d}	0.5^{e}	0.5^{g}	0.6^{i}
ABT	18	83^{a}	1.5^{c}	4.0^{d}	0.5^{e}	0.5^{g}	0.6^{i}
V2	16	43^{b}	1.7^{c}	4.4^{d}	0.3^{e}	6.2^{h}	0.6^{i}
V2	18	67^{a}	1.8^{c}	4.5^{d}	0.2^{e}	6.3^{h}	0.6^{i}
Yoghurt	12	42^{b}	1.8^{c}	4.0^{d}	1.0^{f}	—	—

* Viscosity measured after 2 min of shear thinning using a shear rate of 1207 s^{-1} at 10 °C. Values are the mean of three measurements.

† Texture measured at a speed of 100 cm min^{-1}. Values are the mean of three measurements.

‡ The initial pH of the M40 medium was 7.4.

Data in the same column with different letters are significantly different ($P < 0.05$).

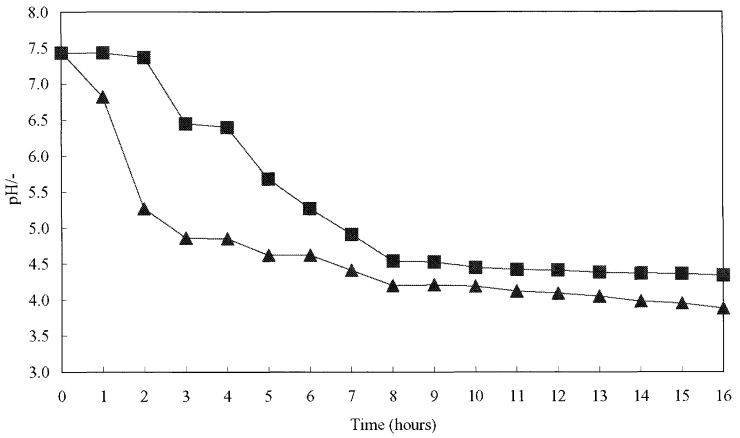

Figure 1. pH profiles in the M40 substrate (16%) during fermentation using two different yoghurt cultures, V2 (squares) and ABT (triangles).

days of storage. The yoghurt culture showed good survival over the whole storage period (Fig 2).

Physical properties

The viscosity in the M40 substrate after fermentation was higher when xanthan gum had been added (Table 3) under the same temperature conditions. The fermented M40 substrate with a dry matter content of 16% and containing 0.03% xanthan gum gave a syneresis of less than 1 ml, compared with the yoghurt control which gave a syneresis of 13 ml (Table 4). The product containing M40 oat base with a dry matter content of 16%, 0.03% xanthan gum and 1.0% fat was selected for the sensory evaluation, as it was subjectively rated as the product with the best yoghurt-like appearance. The viscosity of this sample was 75 mPa s and the a_w value was 0.98, whereas for the yoghurt control they were 42 mPa s and 0.97 respectively. The sample exhibited a colour that was not as light as the milk control; however, both its lightness in colour (*L* value) and green light absorbance (*a* value) were close to those of the fermented, non-dairy control (Sevea$^{(R)}$) (Table 5). The absorbance of yellow/blue light was considerably lower (*b* value). This low value may be an indicator for the general impression of yellowness of oat-based products.

Sensory evaluation

Results of the intensity evaluation are from six fermented products, both plain and flavoured. Flavoured yoghurt and two commercial, fermented, non-dairy products were used as controls and are included in Table 6. In general, the panellists gave a higher score to the flavoured products than to the unflavoured ones. Oat flavour was found to be less apparent in the flavoured products. The flavoured product fermented with the ABT culture was considered to have the best appearance among the oat-based products. A ranking-for-preference test assessed the influence of different yoghurt cultures and the use of flavour in the products (Table 7). The flavoured product (ABT^a) with lower pH (3.8) was ranked higher than the product with less acidity (V2^a) (4.3). Both products were ranked lower than the yoghurt

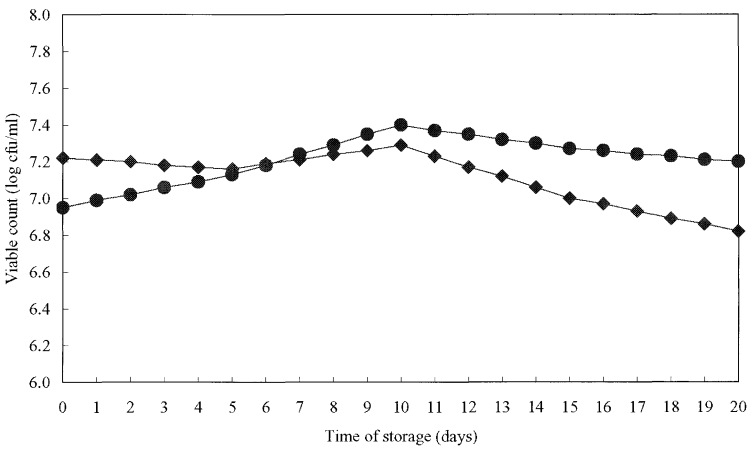

Figure 2. Survival of the V2 culture consisting of *Lactobacillus delbrueckii* subsp *bulgaricus* (circles) and *Streptococcus salvarius* subsp *thermophilus* (diamonds) in the M40 medium (16%) during 20 days of storage at 8 °C.

Yoghurt culture	Xanthan gum (%)	Viscosity at 25°C* (mPas)	Viscosity at 10°C* (mPas)
ABT	0.03	$104_{(2.1)}$–$88_{(2.8)}$ [a]	$>250_{(0.0)}$–$>250_{(0.0)}$ [†c]
ABT	0.04	$109_{(6.5)}$–$98_{(3.5)}$ [a]	$>250_{(0.0)}$–$>250_{(0.0)}$ [†c]
V2	0.03	$83_{(5.5)}$–$73_{(2.5)}$ [b]	$111_{(1.1)}$–$105_{(6.7)}$ [d]
V2	0.04	$101_{(2.0)}$–$92_{(2.1)}$ [a]	$>250_{(0.0)}$–$>250_{(0.0)}$ [†c]

Table 3. Viscosity in the M40 substrate (16%) fermented with two different starter cultures using two different concentrations of xanthan gum in the final product

* Viscosity measured during 2 min of shear thinning using a shear rate of 1207 s^{-1}. Values are the initial and final values of the measuring period and are the mean of three measurements. The figures in parentheses are the standard deviations.
† No measurable value at the shear rate used.
Data in the same column with different letters are significantly different ($P < 0.05$).

control that was significantly preferred. The biplot of two principal components, PC1 and PC2, is shown in Fig 3. PC1 was mainly characterised by oat flavour, whereas PC2 was characterised by acidity and sweetness. The unflavoured products, together with those flavoured with mixed berry jam, were well distributed in PC1, indicating that these products had the most evident oat flavour. The other products were all distributed in PC2, being higher in acidity or sweetness and also being the products with a higher grading for consistency, mouthfeel and overall appearance.

DISCUSSION

In our study, two different commercial starter cultures were used. The V2 culture is used in ordinary yoghurt production and the ABT culture has a documented ability to ferment maltose. Viable counts of the V2 culture, 6.0×10^6 for the *L delbrueckii* subsp *bulgaricus* strain and 1.5×10^7 for the *S salivarius* subsp *thermophilus* strain after 20 days of storage, are similar to those of yoghurt. The increased cell number of *S salivarius* subsp *thermophilus* during the first 10 days in the fermented product and its decrease thereafter have also been reported by others in fermented soymilk.[23] The final pH (4.3) in the product was higher than in ordinary yoghurts. The use of the ABT culture, composed of *S salivarius* subsp *thermophilus*. *L acidophilus* and *Bifidobacterium* spp, gave a lower final pH (3.9) and also a more sour taste and fresh aroma, defined as a typical yoghurt flavour,[24] in comparison with the product fermented with the V2 culture. Obviously, this is the result of the ability of the starter culture to ferment maltose, which is the main fermentable carbohydrate in the substrate. Titratable acidity (0.5%) was, however, low in ABT and V2 compared with the yoghurt control (1.0%). Similar results have been observed in other fermented, non-dairy products.[10]

The dry matter content of the oat base was selected to achieve a product with a texture sufficiently similar to that of yoghurt.[25] A desired yoghurt texture has good firmness and minimal syneresis. Adding xanthan gum as stabiliser improved both the viscosity and consistency. Xanthan gum has a high stability over the pH range from 1 to 11 in aqueous solutions,[26] and its use gave a more yoghurt-like product showing a cohesive, continuous and homogeneous texture with high viscosity. However, its consistency was not as thick and creamy as that of ordinary yoghurt. Further, the fermented product had a more compact than creamy consistency. The stability and firmness of the product were shown by the low susceptibility to syneresis in comparison with the yoghurt. The low susceptibility to syneresis may also be a result of the ability of β-glucans to entrap water within the three-dimensional network of the product. Also, no phase

Table 4. Syneresis measured for the M40 susbstrate after fermentation with the V2 culture in comparison with a plain yoghurt control with 12% dry matter. To the M40 substrate, xanthan gum (0.03% w/v) was added and the final dry matter content of the substrate was 16 or 18% with and without the addition of fat (1% w/w)

Dry matter (%)	Fat (%)	Syneresis* (ml)
16	1.9[†a]	$<1_{(0.0)}$ [d]
16	0.9[‡b]	$<1_{(0.0)}$ [d]
18	2.1[†a]	$<1_{(0.0)}$ [d]
18	1.1[‡b]	$<1_{(0.0)}$ [d]
12[#]	3.2[c]	$13_{(2.5)}$ [e]

* Syneresis measured after centrifugation at $1310 \times g$ for 10 min.
† Addition of fat (1% w/w) to the M40 substrate.
‡ No addition of fat.
# Plain yoghurt control.
Values are the mean of three measurements. The figures in parentheses are the standard deviations.
Data in the same column with different letters are significantly different ($P < 0.05$).

Table 5. *L*, *a* and *b* values for the fermented products in comparison with a commercial, non-dairy product (Sevea®) and a yoghurt control

Product	L	a	b
V2	$74.8_{(0.02)}$ [a]	$-0.5_{(0.01)}$ [c]	$18.9_{(0.70)}$ [e]
ABT	$75.4_{(0.02)}$ [a]	$-0.5_{(0.01)}$ [c]	$19.4_{(0.02)}$ [e]
Sevea®	$77.8_{(0.00)}$ [a]	$-0.4_{(0.01)}$ [c]	$15.6_{(0.00)}$ [f]
Yoghurt	$92.0_{(0.09)}$ [b]	$-3.6_{(0.02)}$ [d]	$12.0_{(0.03)}$ [g]

Values are the mean of three determinations. The figures in parentheses are the standard deviations.
Data in the same column with different letters are significantly different ($P < 0.01$).

Table 6. Flavour and acceptability profiles of two plain and four flavoured products based on the M40 substrate, using intensity scales

Sample	*Appearance*	*Consistency*	*Mouthfeel*	*Sweetness*	*Acidity*	*Oat flavour*	*Overall acceptability*
V2*	$3.5_{(2.1)}^{d}$	$3.9_{(1.8)}^{f}$	$3.7_{(2.1)}^{h}$	$2.8_{(1.8)}^{j}$	$1.7_{(1.8)}^{l}$	$5.5_{(2.2)}^{n}$	$3.5_{(1.8)}^{p}$
V2*,[a]	$4.6_{(2.1)}^{d}$	$3.3_{(1.8)}^{f}$	$4.5_{(1.8)}^{i}$	$5.7_{(1.8)}^{k}$	$2.4_{(1.9)}^{l}$	$4.9_{(2.8)}^{n}$	$4.6_{(1.1)}^{p}$
V2*,[b]	$3.8_{(0.4)}^{d}$	$4.8_{(1.5)}^{f}$	$5.0_{(1.0)}^{i}$	$6.0_{(1.0)}^{k}$	$1.6_{(0.9)}^{l}$	$2.2_{(2.6)}^{o}$	$5.2_{(1.6)}^{q}$
ABT†	$4.1_{(1.9)}^{d}$	$2.7_{(1.4)}^{f}$	$3.9_{(1.9)}^{h}$	$1.9_{(1.4)}^{j}$	$4.6_{(2.6)}^{l}$	$5.5_{(2.5)}^{n}$	$2.8_{(2.2)}^{p}$
ABT†,[a]	$5.3_{(1.9)}^{d}$	$3.1_{(1.4)}^{f}$	$4.0_{(2.4)}^{h}$	$4.6_{(1.4)}^{k}$	$2.9_{(2.6)}^{l}$	$4.8_{(2.5)}^{n}$	$4.4_{(2.2)}^{p}$
ABT†,[b]	$5.2_{(1.8)}^{d}$	$4.8_{(2.4)}^{f}$	$5.4_{(1.9)}^{i}$	$5.4_{(0.9)}^{k}$	$2.6_{(2.3)}^{l}$	$2.6_{(2.7)}^{o}$	$5.2_{(1.6)}^{q}$
Sevea®‡	$2.8_{(1.8)}^{d}$	$4.3_{(2.0)}^{f}$	$3.7_{(1.9)}^{h}$	$5.0_{(2.7)}^{k}$	$1.8_{(1.7)}^{l}$	$4.3_{(1.9)}^{n}$	$3.1_{(1.6)}^{p}$
Sevea®‡,[c]	$6.1_{(1.3)}^{e}$	$6.1_{(1.9)}^{g}$	$6.3_{(1.9)}^{i}$	$5.8_{(2.0)}^{k}$	$3.2_{(1.5)}^{l}$	$1.3_{(1.8)}^{o}$	$5.6_{(1.8)}^{q}$
Yoggi®#,[a]	$6.6_{(1.5)}^{e}$	$4.7_{(1.3)}^{f}$	$6.1_{(1.7)}^{i}$	$5.6_{(1.7)}^{k}$	$4.3_{(2.0)}^{m}$	$0.9_{(1.7)}^{o}$	$6.0_{(1.9)}^{q}$

The intensity scales were set using 9 cm lines. Figures are mean values ($N = 13$) of distances marked by panellists from 0 (no perception) to 9 (highest value of perception). The figures in parentheses are the standard deviations.

* M40 fermented with *Streptococcus salvarius* subsp *thermophilus* and *Lactobacillus delbrueckii* subsp *bulgaricus* (V2).

† M40 fermented with *Streptococcus salvarius* subsp *thermophilus*, *Lactobacillus acidophilus* and *Bifidobacterium* spp (ABT).

‡ Commercial, fermented, non-dairy product.

Commercial yoghurt flavoured with mixed blackberry jam.

[a] Product flavoured with mixed blackberry jam.

[b] Product flavoured with strawberry jam.

[c] Product flavoured with blackcurrant jam.

Data in the same column with different letters are significantly different ($P < 0.05$).

separation was developed during storage, which is a common problem in yoghurt products.[27] The products were less white (L value) than the yoghurt control but appeared to have the same lightness in colour as the commercial, non-dairy product. The products were also less green (a value) than the yoghurt control, which has also been reported by others.[12] The colour component that showed most similarity to the product tested was yellow/blue (b value), which was high in comparison with that of a yoghurt-like product made of soymilk.[28]

Flavour and acceptability profiles were evaluated using intensity scales. The results showed that oat flavour was less apparent in the flavoured samples, as the scores for oat flavour were lower in these products. This was also confirmed in the ranking-for-preference test. The addition of flavours to the products also resulted in a higher overall acceptability, although it was not as high as for the yoghurt control. The problem of masking non-yoghurt flavours in fermented, non-dairy products has been reported by others.[10,11] The remarks by the panellists on the oat flavour of the yoghurt and soya-based products is of interest, since it indicates that oat flavour should be considered a general off-flavour which does not necessarily come from oats. To obtain an overview of the parameters investigated in the intensity test of the different products, principal component analysis (PCA) was used to visualise each sample as a point in a two-dimensional plane defined by two principal components (Fig 3).[29,30] The co-ordinates (scores) for a sample are a function of the values for the sample in question. Samples with similar values for many of the variables (properties) studied appeared close to each other, whereas those with large differences between different variables appeared far apart. The plot of PCA showed evenly distributed samples in both PC1 and PC2 (Fig 3). The products were clustered into two classes: the products containing strawberry flavour (ABT^b, $V2^b$) were distributed in PC2, while the others (ABT^a, $V2^a$, V2*) were distributed in PC1. Within each group the products are characterised by acidity and sweetness. Overall appearance was well correlated with mouthfeel and to some extent also with consistency. By using the PCA model, it was shown that appearance, overall appearance, consistency and sweetness were increased by adding strawberry jam to the products and that the panellists did not appreciate the oat flavour.

Table 7. Ranking for preference to evaluate the addition of flavours and the use of different yoghurt cultures

Product	*Rank sum*	*Preference*[¶]
Yoggi®*	38	1
ABT†[a]	33	1
V2‡[a]	29	1
ABT†	22	2
V2‡	20	2
Sevea®#	20	2

¶ Data with different figures are significantly different ($P < 0.05$).

* Commercial yoghurt flavoured with mixed blackberry jam.

† M40 fermented with *Streptococcus salvarius* subsp *thermophilus*, *Lactobacillus acidophilus* and *Bifidobacterium* spp (ABT).

‡ M40 fermented with *Streptococcus salvarius* subsp *thermophilus* and *Lactobacillus delbrueckii* subsp *bulgaricus* (V2).

Commercial, fermented, non-dairy product.

[a] Product flavoured with mixed blackberry jam.

CONCLUSIONS

The fermented, oat-based, yoghurt-like product developed in this study was a product with an appearance

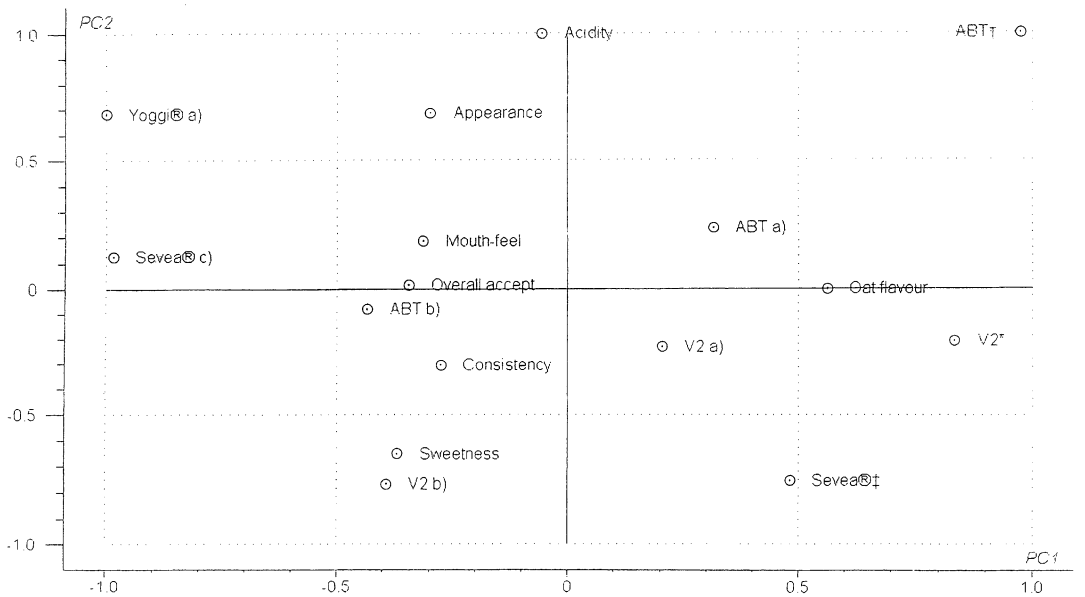

Figure 3. Plot of the first two principal components (PC1 and PC2) from analyses of six different yoghurt-like products based on the M40 medium (16%) (ABT† plain, ABT[a] flavoured with mixed berry jam, ABT[b] flavoured with strawberries; V2* plain, V2[a] flavoured with mixed blackberry jam, V2[b] flavoured with strawberry jam), two commercial products based mainly on soya (Sevea®‡* plain, Sevea®[c] flavoured with blackcurrant jam) and one yoghurt (Yoggi®[a] flavoured with mixed blackberry jam).

and taste that were found to be acceptable. Fermentation with lactic acid bacteria led to acid development, consumption of carbohydrates, formation of flavours and viable counts similar to those of yoghurt. As oat is a palatable cereal, there were no negative off-flavours that needed to be masked. Fermentation and storage were found to have small effects on the β-glucan content of the products. This study shows a new possibility to make an acceptable, fermented product based mainly on oats that can be suggested as an alternative to similar products based on other raw materials. A deeper nutritional and physiological investigation of the product and its effects will be conducted.

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