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Effect of various plant starches on the quality characteristics of starch-based sweetened cow milk yoghurt

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Abstract

In this study, the textural, rheological and colour properties of different starch-based sweetened cow milk yoghurt were analyzed. Stickiness increased with increased addition level of modified starch for both homogenized (-2.231 to -5.304 N) and unhomogenized (-1.505 to -4.834 N) yoghurt sample. Firmness increased linearly for unhomogenized cow milk yoghurt sample at different incorporation level (3.019 to 4.887 N) but the homogenized cow milk yoghurt samples did not shown any clear significant difference. Viscosity also increased with increased addition level of modified starch and unhomogenized yoghurt sample at different incorporation level of modified starch showed clear and significant difference from sample to sample. Firmness, stickiness and viscosity of potato starch-based cow milk yoghurt with homogenization did not show any significant difference, but unhomogenized yoghurt sample showed linear increase of viscosity and firmness that ranged from 0.213 to 0.525 Pa.s and from 2.669 to 4.014 N, respectively. Stickiness of unhomogenized sample also increased with increased potato starch incorporation level. Viscosity increased with increased corn starch incorporation for homogenized sample. The pH values were more or less similar and the colour values showed it was lightness as white for all cases. The highest incorporation level (2%) was found for corn starch followed by potato (1.5%) and modified (1.0%) starch.

Keywords: Plant starches, Quality characteristics, Cow milk, Sweetened yoghurt

Introduction

Milk being a product of biological origin is extremely vulnerable to attack by microbes because it is a good source of nutrients such as carbohydrate (4.5 – 5.25%), protein (3 – 4 %), fat (3 – 4.5%), minerals (approx. 275 mg/100g) and vitamins (approx. 15 mg/100g) but the major component of milk is water (87%) (Jones, 2002). The conversion of milk to yoghurt is agglomeration of casein micelles into a three-dimensional network structure. Yoghurt is a popular fermented milk product that is produced round the world by acid coagulation of milk without drainage. Yoghurt are prepared by fermentation of milk bacterial cultures consisting of a mixture of *Streptococuss subsp. thermophiles and Lactobacillus delbrueckii subsp. bulgaricus*. Some bacterial strains used in cultures for manufactures of yoghurt or other fermented milks are known to produce polysaccharides outside the cell wall, called exopolysaccharides. The use of such strains modifies the physical properties of the fermented milk (Bouzar *et al*., 1997; Hassan *et al*., 2001). Yoghurt manufacturing processes are a little different depending on the country. But, it always comprises a lactic acid fermentation that brings milk to gelification due to destabilization of the protein system. Texture, consistency and flavour are its main quality parameters. Consistency of yoghurt is dependent on its structure, a protein network formed by casein micelles strings and/or clusters entrapping serum and fat globules (Kalab *et al*., 1983). Complex interactions can be established between these three components (Lucey and Singh, 1998). For yoghurt quality, texture is one of the essential components. Texture represents all the rheological and structural attributes perciptible by means of mechanical, tactile and, when appropriate, visual and auditory receptors for food products.

Lactic acid had been found as a key taste component in yoghurt from the taste point of view. Other organic acids and some additives are also involved in the taste of yoghurt (Tamime and Robinson, 1999). Carbonyl compounds such as acetaldehyde, diacetyl, acetoin and acetone are by far the most important components responsible for characteristic/typical aroma of plain yoghurt. These volatiles are produced during the fermentation stage (Kwak *et al*., 1996; Stanley, 1998; Tamime and Robinson, 1999).

Starch is a carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds. This polysaccharide is produced by most green plants as an energy store. It is the most common carbohydrate in human diets and is contained in large amounts in such staple food as potatoes, corn, wheat, rice, cassava, tapioca, etc. Pure starch is white in colour, tasteless and odourless powder that is insoluble in cold water or alcohol. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight (Brown and Poon, 2005). Starch is semi crystalline in nature with varying levels of crystallinity. The crystallinity is associated exclusively with the amylopectin component, while the amorphous regions mainly represent amylose (Zobel *et al*., 1998). The physico-chemical properties and functional characteristics of starch that are imparted to the aqueous systems and their uniqueness in various food applications vary with the biological origin (Svegmark and Hermansson, 1993). Starch contributes the textural properties to many foods. It has many industrial applications as a thickener, stabilizer, gelling agent, water retention agent, bulking agent, adhesive, etc. Many methods of characterizing starch have been developed. A large number of techniques such as differential scanning calorimetry (DSC), X-ray diffraction (Zobel *et al*., 1998) and small angle neutron scattering (Jenkins, 1994) have been used to study the gelatinization behaviour of starches.

Starch exhibits unique viscosity behaviour with change of temperature, concentration and shear rate (Nurul *et al*., 1999). The brabender visco-amylograph, rapid visco-analyser and rotational viscometers have been used for measuring starch paste viscosity. Many scientists have also used the dynamic rheometer for studying the viscoelastic or rheological properties of starches (Hsu, *et al*., 2000; Lii, *et al*., 1996).

Many times the addition of functional ingredients to food products results in the changes in the sensory properties of the product that could lead to a decrease in consumer's overall acceptability. Generally, consumers are not willing to accept functional foods which taste worse than conventional foods (Hilliam, 2003). For that reason, it is important to develop the functional food without changing the sensory characteristics because of consumers' reaction.

The purposes of this study were to prepare starch-based sweetened yoghurt (with homogenization and without homogenization) of cow milk and to evaluate the textural, rheological, colour and sensory properties of yoghurt.

Materials and Methods

The experiment was conducted in the Laboratory of Food Technology, Division of Dairy Technology, National Dairy Research Institute (NDRI), Karnal, Haryana, India.

Chemicals

Cow milk wascollected from NDRI, Karnal, Haryana, India; analytical grade sulfuric acid and amyl alcohol were purchased from Merck Specialities Pvt. Ltd., Mumbai, India. Potato and corn starch were procured from Aryan International, Jonapur, New Delhi, India. The DELVO DSL Direct set^{TM} Lyophilised starter cultures were procured from DSM Food Specialities, P.O. Box 1, 2600 MA Delft, The Netherlands. Other solvents and reagents used were of analytical grade and from laboratories stock.

Determination of fat in milk (Gerber method)

Mixture of 90 ml of sulphuric acid with 10 ml of distilled water is called Gerber acid. Gerber acid ten milliliters was transferred into milk butyrometer (range 0 to 10%) using an automatic measure. The milk sample (10.75 ml) was slowly transferred from the side of the butyrometer closed with a lock stopper and shaken well. The mixer contents were centrifuged for 5 min at 1100 to 1200 rpm and the fat that appeared as a colourless column was read directly on the butyrometer stem.

Estimation of Solids-Not-Fat (SNF)

The SNF is the collective term given to the various components of milk other than fat. The SNF content of milk was calculated by determining the specific gravity of milk. The sample was mixed well avoiding incorporation of air or foam formation. The temperature of milk sample was adjusted to measuring temperature prescribed for the BIS lactometer (27ºC). Sufficient milk was poured into the glass or steel cylinder to allow free floating of lactometer. It was then placed in the milk and allowed to float till it stopped and assumed a constant level. The lactometer reading and temperature of milk was recorded at the same time. This was the lactometer reading (LR). The corrected lactometer reading (CLR) was obtained from the standard table for corresponding temperature. The SNF and/or TS content were calculated using the following formulas:

Percent SNF = CLT/4 + (0.25*fat%) + 0.44
Percent Total Solids = CLT/4 + (0.25*fat%) + 0.44

Preparation of yoghurt

Fresh raw cow whole milk was taken and standardized to 3.0% fat and 8.5 SNF. It was heated to 40ºC and added with starch at different levels (0.5, 1.0, 1.5, 2.0 and 2.5%) and power sugar (13%). It was blended and kept for 30 min. After that, it was heated up to 65ºC and homogenized (2000 psi). Another similar batch was prepared without homogenization. Again, the sample was heated up to 95ºC, cooled down to 40ºC and starter culture was added. The sample was kept into incubator at 40ºC for 7 hrs. After that, it was taken out and kept in refrigerator for further analysis.

Determination of pH of different starch-based cow milk yoghurt

The pH of the sample was measured by using EUTECH Instruments, pH700, pH/mV/ºC/ºF meter at ambient temperature.

Colour values measurement

The colour of different starch-based sweetened yoghurt was measured using colourflex instrument (Hunterlab, Hunter Associates Laboratory, Teston, Virginia, USA) provided with the universal software (Ver.$ 1.72). Before the test, the instrument was calibrated with standard black glass and white tile as specified by the manufacturer. The light source was dual beam xenon flash lamp. Colour values were expressed in terms of CIELAB software and expressed in terms L*, a*, b* uniform colour specs, where L* indicates lightness, ranges zero (black) to 100 (white), a* indicates redness (0 to +60) and greenness (0 to -60) and b* is the amount of yellowness (0 to +60) and blueness (0 to -60). Hue angle and chroma were determined. The different starch-based sweetened yoghurt samples were put densely up to 1 cm height in glass sample containers and placed on sample port facing upward. Command was given to the instrument to analyze the colour intensity of the sample by taking flash photograph of the product and results were displaced. Measurements were done in triplicates.

Texture profile analysis

Texture profile analysis plays an important role in understanding various textural attributes. The texture of yoghurt closely related to body and appearance and, hence affects the consumer acceptability. The texture profiles of different starch-based sweetened yoghurt were determined by using Texture Analyzer, TA-XT2i (M/s Stable Micro Systems, UK) fitted with 25 kg load cell. TA-XT2i was calibrated with 5 kg standard dead weight prior to use. The probe P-25 was used for texture profile analysis of different starch-based sweetened yoghurts.

Viscosity analysis using modular compact rheometer

The viscosity of the different starch-based sweetened yoghurt was measured by using modular compact rheometer instrument (Anton Paar, MCR52, Ostfildern, Germany) controlled by the computer aided software (Rheoplus/32, service ver.3.61). Cone and plate geometry (CP75-1, 1.002° inclination) attachment was used with a gap of 0.149 mm. For steady flow measurements, the rheometer was programmed for the set temperature (20ºC) and equilibrated for 2 min following a programmed shear rate

changing from 0.1 to 100 s^{-1} in 5 min. The temperature controlled by Peltier control system. For each test, the volume of sample placed on the plate was covered completely and excess sample was trimmed off. Each time new sample was used and all rheological measurements were carried out in triplicates. Rheological parameters: constant shear rate (γ = 100) and viscosity (μ) were recorded in software.

Sensory analysis

Sensory evaluation was done by a panel of seven trained judges to evaluate the samples for various sensory attributes. The 9-point hedonic scale was used to express the liking or disliking of products, and the panel members requested to judge the sensory quality based on colour and appearance, flavour, acidity, body and texture, and overall acceptability.

Statistical analysis

The data obtained during this study were analyzed using statistical package for social sciences (SPSS version 20).

Results and Discussion

Textural, rheological and colour properties of cow milk yoghurt

(i) Modified starch-based sweetened yoghurt

The textural and rheological properties of modified starch-based sweetened cow milk yoghurt (with and without homogenization) at different substitution levels are tabulated in Table 1 and Table 2. Stickiness increased with increased modified starch addition level for both with (from -2.231 to -5.304) and without homogenization (from -1.505 to -4.834) samples. Firmness also increased linearly for the sample of without homogenization at different incorporation level (from 3.019 to 4.887), but the homogenization samples did not show any clear difference because the modified starch lost its gelatinization power due to homogenization. Viscosity also increased with increased starch addition level and without homogenization sample showed clear and significant difference from sample to sample. The pH values for all cases ranged from 4.12 to 4.65. For all samples, L*, a* and b* values indicated that the samples were white, greenness and yellowness, respectively.

(ii) Potato starch-based sweetened yoghurt

Table 1. Textural, rheological and colour properties of modified starch-based sweetened cow milk yoghurt with homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of modified starch at different level with homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	4.25±0.03	4.2±0.01	4.13±0.013	4.42±0.2	4.22±0.01	4.12±0.01
Textural						
Firmness (N)	3.272±0.258	3.941±0.203	3.897±0.104	3.477±0.114	3.231±0.053	4.409±0.113
Stickiness (N)	-2.231±0.059	-2.703±0.144	-2.92±0.038	-3.113±0.176	-3.838±0.09	-5.304±0.302
Rheological						
Viscosity (Pa.s)	0.206±0.001	0.265±0.015	0.275±0.017	0.315±0.001	0.395±0.002	0.644±0.001
Colour						
L*	82.61±0.002	83.49±0.07	83.97±0.1	83.47±0.1	82.72±0.1	83.26±0.008
a*	-1.68±0.001	-1.1±0.01	-1.33±0.04	-1.42±0.02	-1.39±0.03	-1.43±0.004
b*	8.47±0.05	9.58±0.06	9.81±0.07	9.61±0.3	9.68±0.06	10.07±0.03
C	8.76	9.64	9.90	13.65	13.45	10.17
Hº	-79.14	-83.45	-82.25	-81.59	-81.83	-81.02

Here; $C = (a^2 + b^2)^{1/2}$; $H^o = \tan^{-1}(b/a)$

Table 2. Textural, rheological and colour properties of modified starch-based sweetened cow milk yoghurt without homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of modified starch at different level without homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	4.36±0.02	4.71±0.02	4.6±0.01	4.57±0.3	4.48±0.03	4.44±0.04
Textural						
Firmness (N)	4.235±0.235	3.556±0.125	4.043±0.089	4.435±0.182	5.407±0.194	6.009±0.126
Stickiness (N)	-3.259±0.098	-4.069±0.274	-4.356±0.12	-5.101±0.362	-5.511±0.255	-6.145±0.153
Rheological						
Viscosity (Pa.s)	0.277±0.009	0.508±0.004	0.557±0.006	0.702±0.002	0.637±0.007	0.703±0.008
Colour						
L*	83.6±0.11	81.73±0.08	81.43±0.07	80.72±0.00	83.49±0.25	82.37±0.07
a*	-0.90±0.02	-0.81±0.03	-0.34±0.06	-1.07±0.03	-1.05±0.02	-1.21±0.04
b*	12.98±0.04	11.99±0.09	12.03±0.14	11.77±0.03	13.11±0.2	13.15±0.04
C	11.68	9.71	4.09	12.59	13.76	15.91
Hº	-86.03	-86.14	-88.38	-84.81	-85.42	-84.74

Here; $C = (a^2 + b^2)^{1/2}$; $H^o = \tan^{-1}(b/a)$

Textural, rheological and colour properties of potato starch-based sweetened cow milk yoghurt with and without homogenization are given in Table 3 and Table 4. Firmness, stickiness and viscosity of potato-based sweetened cow milk yoghurt with homogenization samples did not show any clear significant difference. During homogenization, potato starch lost its gelatinization capacity. For the sample without homogenization, it showed linear increase of viscosity and firmness that ranged from 0.213 to 0.525 and 2.669 to 4.014, respectively. Stickiness of without homogenization sample also increased with increased starch incorporation level. The pH values were within the range of 4.13 to 4.51 for all samples. All samples were white in colour with slight greenness and yellowness.

(iii) Corn starch-based sweetened yoghurt

Table 3. Textural, rheological and colour properties of potato starch-based sweetened cow milk yoghurt with homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of potato starch at different level with homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	4.42±0.01	4.46±0.02	4.4±0.0	4.35±0.01	4.33±0.01	4.43±0.02
Textural						
Firmness (N)	3.649±0.114	3.945±0.04	3.642±0.075	3.523±0.127	3.351±0.114	3.659±0.08
Stickiness (N)	-2.288±0.045	-3.185±0.059	-4.027±0.057	-3.729±0.174	-3.514±0.255	-3.567±0.013
Rheological						
Viscosity (Pa.s)	0.202±0.008	0.322±0.007	0.364±0.003	0.407±0.002	0.386±0.002	0.355±0.005

Table 4. Textural, rheological and colour properties of potato starch-based sweetened cow milk yoghurt without homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of potato starch at different level without homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	4.13±0.01	4.19±0.03	4.45±0.02	4.51±0.02	4.15±0.03	4.37±0.01
Textural						
Firmness (N)	2.669±0.078	2.546±0.105	2.975±0.089	3.612±0.028	3.751±0.661	4.014±0.154
Stickiness (N)	-2.275±0.021	-3.10±0.481	-3.32±0.451	-3.096±0.062	-3.86±0.48	-3.95±0.2
Rheological						
Viscosity (Pa.s)	0.213±0.013	0.34±0.005	0.351±0.007	0.385±0.008	0.402±0.001	0.525±0.012

The textural, rheological and colour properties data of corn starch-based sweetened cow milk yoghurt with and without homogenization are presented in Table 5 and Table 6. Firmness and stickiness did not show any clear significant difference for the homogenization sample. Due to homogenization, starch lost and reduced its pasting properties. Viscosity increased with the increase of corn starch incorporation for homogenization sample. The pH values were ranged from 4.44 to 5.17. The colour values of all samples were same as before. For unhomogenized sample, viscosity, firmness and stickiness increased with increased of corn starch incorporation level.

Table 5. Textural, rheological and colour properties of corn starch-based sweetened cow milk yoghurt with homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of corn starch at different level with homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	5.15±0.01	4.44±0.02	4.68±0.02	4.58±0.01	4.9±0.01	5.17±0.02
Textural						
Firmness (N)	3.019±0.038	4.194±0.172	3.673±0.051	3.449±0.038	3.957±0.084	4.296±0.171
Stickiness (N)	-1.505±0.03	-2.817±0.096	-3.592±0.132	-3.439±0.138	-3.478±0.062	-3.17±0.312
Rheological						
Viscosity (Pa.s)	0.142±0.002	0.252±0.002	0.322±0.001	0.33±0.002	0.445±0.003	0.515±0.005

Table 6. Textural, rheological and colour properties of corn starch-based sweetened cow milk yoghurt without homogenization

Parameters	Control	Sweetened cow milk yoghurt incorporation of corn starch at different level without homogenization				
		0.5%	1.0%	1.5%	2.0%	2.5%
pH	4.45±0.01	4.5±0.02	4.53±0.03	4.65±0.01	4.51±0.02	4.49±0.01
Textural						
Firmness (N)	3.019±0.038	3.674±0.11	3.96±0.093	4.568±0.203	4.595±0.051	4.887±0.236
Stickiness (N)	-1.505±0.03	-3.578±0.144	-4.009±0.018	-4.849±0.034	-4.585±0.352	-4.834±0.465
Rheological						
Viscosity (Pa.s)	0.142±0.002	0.464±0.006	0.558±0.006	0.636±0.005	0.689±0.009	0.761±0.007

Sensory properties of different starch-based sweetened cow milk yoghurt

Yoghurt from unhomogenized milk for all treatments responded positively with the level of incorporation of different starches but the homogenized samples responded positively in a few cases only. Colour values, however, remained unchanged in all treatments. So, the results of sensory evaluation of different starch-based yoghurt from cow milk without homogenization are reported only.

The sensory attributes of sweetened cow milk yoghurt with incorporation of modified starch at different levels without homogenization based on colour and appearance, flavour, acidity, body and texture, and overall acceptability were significantly ($p<0.01$) different (Table 7). Thus, the sensory attributes of all the samples showed various degrees of acceptability. However, the overall acceptability was the highest at 1.0% incorporation level of modified starch without homogenization.

Similarly, the sensory properties of sweetened cow milk yoghurt incorporation of potato starch at different level without homogenization are given in Table 8. The sensory attributes of different samples showed various degrees of acceptability and were significantly different ($p<0.01$). The overall acceptability was the highest at 1.5% incorporation level of potato starch without homogenization.

The sensory qualities based on different attributes for sweetened cow milk yoghurt incorporation of corn starch at different levels without homogenization are given in Table 9. It is seen that all these sensory scores of different samples were significantly different ($p<0.01$) and thus, the samples showed various degrees of acceptability. The highest overall acceptability was found at 2.0% for incorporation level of corn starch for without homogenization.

Table 7. Sensory properties of modified starch-based sweetened cow milk yoghurt without homogenization

Sensory attributes	Control	Sweetened cow milk yoghurt incorporation of modified starch at different level without homogenization					LSD
		0.5%	1.0%	1.5%	2.0%	2.5%	
Colour & appearance	7.5^{a}	7.7^{a}	7.7^{a}	7.6^{a}	7.7^{a}	7.8^{a}	NS**
Flavour	7.4^{abc}	7.2^{c}	7.5^{abc}	7.3^{bc}	7.6^{ab}	7.7^{a}	0.3203*
Acidity	7.4^{ab}	7.1^{c}	7.1^{c}	7.3^{bc}	7.5^{ab}	7.6^{a}	0.2448
Body & Texture	7.3^{ab}	7.5^{a}	7.7^{a}	7.0^{b}	7.5^{a}	7.0^{b}	0.3739
Overall acceptability	7.4^{a}	7.4^{a}	7.4^{a}	7.3^{a}	7.7^{a}	7.5^{a}	NS

* = Significant at 1% level of probability; **NS = Not significant

Table 8. Sensory properties of potato starch-based sweetened cow milk yoghurt without homogenization

Sensory attributes	Control	Sweetened cow milk yoghurt incorporation of potato starch at different level without homogenization					LSD
		0.5%	1.0%	1.5%	2.0%	2.5%	
Colour & appearance	7.1^{c}	7.8^{a}	7.8^{a}	7.8^{a}	7.4^{b}	7.6^{ab}	0.2609*
Flavour	6.8^{c}	7.4^{b}	7.8^{ab}	7.9^{a}	6.9^{c}	7.4^{b}	0.4120
Acidity	7.2^{bc}	7.3^{bc}	7.5^{b}	7.8^{a}	7.1^{c}	7.5^{b}	0.2998
Body & Texture	7.0^{c}	7.4^{b}	7.4^{b}	7.8^{a}	7.1^{c}	7.4^{b}	0.2065
Overall acceptability	7.0^{c}	7.5^{ab}	7.7^{a}	7.7^{a}	6.8^{c}	7.2^{abc}	0.5068

* = Significant at 1% level of probability

Table 9. Sensory properties of corn starch-based sweetened cow milk yoghurt without homogenization

Sensory attributes	Control	Sweetened cow milk yoghurt incorporation of corn starch at different level without homogenization					LSD
		0.5%	1.0%	1.5%	2.0%	2.5%	
Colour & appearance	7.0^{c}	7.8^{a}	7.8^{a}	7.8^{a}	7.4^{b}	7.1^{c}	0.2609*
Flavour	6.3^{c}	6.7^{d}	7.4^{bc}	7.8^{a}	7.7^{ab}	7.3^{c}	0.3539
Acidity	6.8^{c}	6.9^{bc}	7.3^{ab}	7.4^{a}	7.3^{ab}	7.5^{a}	0.4539
Body & Texture	6.8^{c}	7.2^{bc}	7.5^{ab}	7.2^{bc}	7.8^{a}	7.6^{ab}	0.4628
Overall acceptability	6.6^{c}	7.2^{b}	7.7^{a}	7.6^{a}	7.7^{a}	7.3^{ab}	0.3702

* = Significant at 1% level of probability

Conclusion

The purpose of this study was to incorporate different starches to sweetened cow milk yoghurt for increasing textural and rheological properties. The firmness, stickiness and viscosity increased linearly with increase of incorporation level of different starches without homogenization. During homogenization, all starches lost their gelatinization capacity because of that all samples did not show any significant difference for textural and rheological properties. The incorporation level (2%) was higher for corn starch than for potato and modified starch. Further studies are needed for using starches to incorporate into the cow milk sweetened yoghurt.

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