

Effect of hydrocolloid type on physiochemical properties of nonfat drinkable yogurt fermented with ropy and non-ropy yogurt cultures

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Abstract

Drinkable yogurt is defined as a dairy-based yogurt that is drinkable in a liquid form and may or may not include fruit or fruit flavoring. Mouthfeel defects may be affected by processing conditions, starter cultures and stabilizer selection. This research was investigated the effect of hydrocolloid type (gelatin, carboxymethylcellulose or high methoxy pectin) on the sensory characteristics and rheological properties of drinkable yogurts fermented with nonropy and ropy yogurt cultures. The results demonstrated that gelatin-stabilized drinkable yogurt fermented with nonropy and ropy cultures had significantly higher acidity and protein content. Yogurt stabilized with gelatin was the thickest yogurts with lack of whey separation and had a positive significant effect on the sensory characteristics. Drinkable yogurt stabilized with carboxymethylcellulose (CMC) proved to be completely unacceptable as a stabilizer for the yogurt drink. A better understanding of factors contributing to the physical and structural attributes may allow manufacturers to improve the quality of yogurt.

Keywords: Nonfat drinkable yogurt, stabilizers, ropy strain, nonropy strain, rheology, sensory characteristics

Efeito do tipo de hidrocolóide sobre as propriedades físico-químicas de iogurte desnatado bebível fermentados com culturas de iogurte viscosos e não viscosos

Resumo

Iogurte bebível é definido como um iogurte à base de produtos lácteos, que é potável na forma líquida e pode ou não incluir fruta ou aroma de fruta. Alterações de paladar podem ocorrer por condições de processamento, fermentos e seleção estabilizadora. Esta pesquisa investigou o efeito do tipo de hidrocolóide (gelatina, carboximetilcelulose ou alta pectina metoxi) sobre as características sensoriais e propriedades reológicas de iogurtes bebíveis fermentados com culturas de iogurte não viscoso e viscoso. Os resultados demonstraram que o iogurte potável estabilizado com gelatina fermentado com culturas não viscoso e viscoso tinham significativamente maior teor de acidez e proteína. Iogurte estabilizado com gelatina foi os iogurtes mais grossas com a falta de separação de soro e teve um efeito positivo significativo sobre as características sensoriais. Iogurte bebível estabilizado com carboximetilcelulose (CMC) provou ser completamente inaceitável como um estabilizador para a bebida de iogurte. Uma melhor compreensão dos fatores que contribuem para os atributos físicos e estruturais podem favorecer os fabricantes a melhorar a qualidade do iogurte.

Palavras-chave: iogurte desnatado bebível, estabilizadores, tensão viscoso, tensão não viscosa, reologia, características sensoriais

Introduction

Drinkable yogurts are a standout among the healthy dairy beverages being offered today. Drinking yogurts come in just about every flavor we can imagine and range from runny to viscous, sourly unsweetened to overwhelmingly saccharine. The Food and Drug Administration (FDA, 2008) standard of identity for yogurt drinks specifies >8.25% milk solids-not-fat and fat levels to satisfy nonfat yogurt (<0.5%), low-fat yogurt (2%), or yogurt (>3.25%) before the addition of other ingredients (Chandan et al., 2006). These yogurts are positioned as yogurt smoothies. Hydrocolloids gums are added through the processing for two main reasons as thickening or gelling agents and to stabilize the yogurt matrix (Early, 1998; Phillips & Williams 2000; Tamime & Robinson, 1999) that can improve the viscosity, maintain the yogurt structure, inhibit syneresis (FDA, 1996) and alter the mouthfeel (Early, 1998). Drinkable yogurt may be more health promoting when produced with probiotic cultures (*Lactobacillus acidophilus*, *Lactobacillus casei*, *Bifidobacterium bifidum*, *Bifidobacterium longum*, etc.). Exopolysaccharides (EPS) synthesized by lactic acid bacteria (ropy strains) can be utilized to produce yogurt drink (Florea & Costin, 2005) that improved the yogurt texture (Hess et al., 1997; Teggatz & Morris, 1990), improve taste perception (Welman & Maddox, 2003) and have beneficial health effects (Ruas-Madiedo et al., 2002; Welman et al., 2006). Mouthfeel defects may be affected by processing conditions, starter cultures, and stabilizer selection (Maiolino, 2002; Wszolek et al., 2001). Acting as texturizing and stabilizing agents, Exopolysaccharides (EPS) decrease syneresis and improve product stability (De Vuyst & Degeest, 1999). Hydrocolloid selection is crucial, as a particular stabilizer may either reduce or impart chalkiness, depending on the use and other properties (Maiolino, 2002). The objective of this research is to investigate the effect of hydrocolloid type which are classified into animal derived (gelatin), plant extract (pectin) and synthetic hydrocolloids (carboxymethylcellulose, CMC) when using with rope and nonropy strains (lactic acid bacteria) on the sensory characteristics and rheological properties of nonfat drinkable yogurts to improve

of physical and rheological properties.

Material and Methods

Starter cultures

Two types of yogurt cultures were used, ropy and a non-ropy starter cultures, provided by (Chr. Hansen, Product information brochure, 2003). Ropy culture was thermophilic culture YF-L811, which is a characteristic mixture of *Streptococcus thermophilus* (ST) and *Lactobacillus delbrueckii ssp Bulgaricus* (LB) in freeze-dried form. The non-ropy culture was *Streptococcus thermophilus* and *Lactobacillus delbrueckii ssp Bulgaricus*. The yogurt cultures (ropy and non-ropy) were propagated three times consecutively using a 1% (v/v) inoculum volume in 10% reconstituted nonfat dry milk (NDM) at 37°C for 18 h before use a symbiotic blend of *Streptococcus salivarius* subsp *Thermophilus* (ST) and *Lactobacillus delbrueckii* subsp *Bulgaricus* (LB).

Types of hydrocolloids

Three types of hydrocolloids were used in this study and were selected after noting their use in some drinkable yogurts available on the market, while the levels of stabilizers used were selected based upon preliminary studies in the laboratory. These hydrocolloids stabilizers under investigated were gelatin (Type B Beef Skin Gelatin, 250/40 Mesh, Leiner Davis Gelatin, Jericho, NY), carboxymethylcellulose (CMC) (Anqiu Eagle Cellulose Co., Ltd, China) or high methoxy pectin (HMP) (Copenhagen Pectin Factory, Denmark) with concentrations of 0.5% gelatin, 0.2% CMC, 0.1% HMP (w/v).

Drinkable yogurt production

Although there are no standardized procedures for manufacture a drinkable yogurt product, most processors agree on a general process. Hydrocolloids are generally added to the milk (10 % SNF) prior to fermentation. The milk samples were warmed in a water bath to approximately 95 °C before the stabilizers were added under constant rapid stirring. Once the stabilizers had been thoroughly incorporated, the milk was heated to 85°C for 30 minutes (Tamime & Deeth, 1980; Tamime, & Robinson, 1985).

After heat treatment, the milk was immediately cooled to 42 °C, inoculated with 2% yogurt culture of either the ropy or non-ropy strains and was allowed to incubate in a 42°C until a pH of 4.0-4.3 was reached. The fermented milk was refrigerated at 4 °C for 24 h and blending with slow speed then re refrigerated.

Analysis of drinkable yogurt

I. Chemical analysis of drinkable yogurt which related to mouthfeel evaluation.

pH measurement

The pH of the samples was regularly measured at $25 \pm 1^\circ\text{C}$ using a Jonway 705 pH meter prior to measuring the viscosity. The pH meter was calibrated with buffer standards of pH 4 and pH 10 prior to use. 50 ml of each yoghurt drink was placed in a beaker, the probe of the pH meter was inserted and pH value was recorded. This measurement was done on opening of the yoghurt. The probe was rinsed thoroughly with distilled water before used on sample.

Titrateable acidity

The titrateable acidity (TA) was determined according to the method of Seo (2010). Ten ml of bacterial cultures and 20 ml of deionized water were mixed and 0.5 ml of phenolphthalein was added into the mixture. This mixture was titrated with 0.1 M NaOH. The acidity of the bacterial cultures was calculated as percent (%) lactic acid.

Protein content (mg/ml³)

Protein content was measured using the Lowry Method (Lowry et al., 1951) One ml of each drinkable yogurt sample was diluted in 100 ml distilled water and allowed to sit. Dilutions of 0.1, 0.2, 0.3, 0.5, 0.7, and 1.0 ml of drinkable yogurt samples were tested. Three ml of each prepared sample dilution were read with a SP-2000UV UV/V is Spectrophotometer at 650 nm. Protein concentrations generally were determined and reported with reference to standards of a common protein such as bovine serum albumin (BSA). Determine concentrations of original samples from the amount protein, volume/ sample, and dilution factor, if any.

II. Rheological properties

Apparent viscosity η_{app} (cP.s)

A one-point measurement was used as a quality control technique for non-Newtonian fluids. Apparent viscosity was based on measuring resistance to a rotating spindle (Brookfield Model DV III Programmable rheometer) after 24 h of storage in a refrigerator at a constant temperature of 4°C. The instrument was equipped with an 18 measuring head. Test samples were subjected to shear rate a spindle speed of 50 rpm and spindle rotating velocities, at constant temperature of (4°C) and viscosity was recorded after 30 s. All apparent viscosity measurements were expressed in cintipoise seconds (cP.s) and were performed in triplicate.

Whey separation (ml %)

Whey separation of drinkable yogurt was measured using gravity separation. One hundred ml of each sample were poured into glass graduated and placed on an undisturbed shelf in a 2.8 °C cooler. Separation of the serum fluid from the gel matrix was visually measured after storage under refrigeration for 5 days. All samples were evaluated in triplicate.

III. Sensory analysis

Sensory analysis is used in quality control, marketing research, and product development applications (Meilgaard et al., 1999). Nine trained panelists evaluated drinkable yogurts using a 0- to 15-point numerical intensity scales "a 15 cm line scale" (Meilgaard et al., 1999). A sensory panel generated 4 sensory attributes, chalkiness, mouth coating, sourness and off-flavor. Each drinkable yogurt was evaluated in triplicate.

Chalkiness

For dairy products, chalkiness is a mouthfeel attribute that may be considered a defect (Wszolek et al., 2001). Chalkiness was described as the amount of fine chalklike particles perceived when the yogurt is in the mouth (Drake et al., 2000). It defined as both a taste and a feeling of chalky particles on the tongue and behind the teeth during swallowing.

Mouth coating

This is representing the actual mouth coating of a drinkable yogurt product (like heavy whipping cream).

Sourness and Off-flavor

Sourness was carried out according to Ott et al. (1997) however; off-flavor was carried out according to the method described by Santos et al. (2003).

Statistical Analyses

Statistical analysis was performed by using the general linear model (GLM) procedure of Statistical Analysis System (SAS, 1988). Data

were analyzed by one-way ANOVA followed by LSD test ($P \leq 0.05$).

Results

Chemical analysis of drinkable yogurt
pH values and titratable acidity (TA) values, expressed as % lactic acid

Both gelatin and HMP-stabilized yogurts with nonropy starter culture showed a higher acidity (pH = 3.8 and 3.75) in comparison to the acidity of yogurt stabilized with the same stabilizers and ropy starter culture (pH = 4.0 and 3.96 respectively); whereas, CMC-stabilized yogurt showed nearly similar acidity (pH = 3.99) with both starter cultures (Table 1).

Table 1. Chemical analysis of drinkable yogurt.

Type of stabilizer	Type of culture	pH value	Titratable acidity (%) lactic acid	Protein content (mg/ml) ³
Gelatin	Nonropy	3.80 ± 0.23	1.124 ± 0.11	0.890 ± 0.13
	Ropy	4.00 ± 0.21	0.873 ± 0.16	0.858 ± 0.21
CMC	Nonropy	3.99 ± 0.11	0.782 ± 0.09	0.245 ± 0.04
	Ropy	4.00 ± 0.12	0.767 ± 0.06	0.278 ± 0.03
HMP	Nonropy	3.75 ± 0.23	1.080 ± 0.19	0.538 ± 0.07
	Ropy	3.96 ± 0.31	0.885 ± 0.12	0.514 ± 0.06

Gelatin = 0.5%; CMC = 0.2%; HMP = 0.1%. Nonropy = (ST+LB); Ropy = Thermophilic culture YF-L811; Inoculation at 1% (v/v). Data are expressed as mean ± SE and were analyzed by SAS (t) test, one-way ANOVA followed by LSD test ($P \leq 0.05$).

Protein content (mg/ml)³

Table (1) showed the mean protein contents for all drinkable yogurts produced. The protein content was higher for the nonropy yogurts products made with gelatin or HMP (0.890 and 0.538 mg/ml) than ropy (0.858 and 0.514 mg/ml) respectively; whereas, ropy yogurt made with CMC was higher (0.278 mg/ml) than nonropy yogurt made with CMC (0.245 mg/ml).

II. Rheological properties**Apparent viscosity η_{app} (cP.s)**

Gelatin-stabilized yogurt with both nonropy and ropy cultures was the thickest yogurts (72.45 and 67.31 cP), followed by the yogurts made with HMP (68.71 and 65.82 cP) respectively. The yogurt made with CMC and both nonropy and ropy cultures demonstrated the least amount of shear thinning (low η_{app}) (58.50 and 68.71 cP) (Table 2).

Table 2. Rheological properties of drinkable yogurt

Type of stabilizer	Type of culture	Viscosity (cP.s)	Whey separation (%)
Gelatin	Nonropy	72.45 ± 4.21	0.0
	Ropy	67.31 ± 4.93	0.0
CMC	Nonropy	61.31 ± 3.76	24.0 ± 1.96
	Ropy	58.50 ± 3.54	10.3 ± 1.55
HMP	Nonropy	68.71 ± 4.78	0.0
	Ropy	65.82 ± 2.98	0.0

Gelatin = 0.5%; CMC = 0.2%; HMP = 0.1%. Nonropy = (ST+LB); Ropy = Thermophilic culture YF-L811; Inoculation at 1% (v/v). Data are expressed as mean ± SE and were analyzed by SAS (t) test, one-way ANOVA followed by LSD test ($P \leq 0.05$).

Whey Separation (%)

The average percent of whey separation for these products are listed in Table (2). The drinkable yogurt samples made with gelatin and HMP had lack of whey separation until 5 days (0.0%) whereas, all of the CMC samples separated usually were starting on the first day. The yogurt made with CMC and both non-ropy and ropy cultures had whey separation (24.0 and 10.3%). Beside the rheological properties of drinkable yogurt.

III. Sensory analysis

Sensory analysis is used to characterize and measure sensory attributes of products with

stabilizer and exopolysaccharide from ropy strain.

Chalkiness (mouthfeel defects)

The type of stabilizer and culture influenced perceived yogurt chalkiness, as seen in Table (3). Yogurt made with HMP had significantly ($p < 0.05$) chalkier than products made with the other two hydrocolloids. Chalkiness of HMP-stabilized yogurt with both non-ropy and ropy cultures was 8.5 and 8.0 points whereas of CMC-stabilized yogurt with both non-ropy and ropy cultures was 8.0 and 7.0 points. Gelatin-stabilized yogurt recorded lowest chalkiness with both non-ropy and ropy cultures that was 6.9 and 6.5 points.

Table 3. Mean scores of the sensory characteristics of drinkable yogurts.

Type of stabilizer	Type of culture	Chalkiness	Mouth coating	Sourness	Off-flavor
Gelatin	Nonropy	6.9 ± 0.81	9.0 ± 1.22	9.38 ± 0.21	1.35 ± 0.21
	Ropy	6.5 ± 0.33	8.0 ± 0.85	7.14 ± 0.26	1.16 ± 0.23
CMC	Nonropy	8.0 ± 0.42	5.5 ± 0.78	5.72 ± 0.32	3.19 ± 0.31
	Ropy	7.0 ± 0.51	3.0 ± 0.21	4.28 ± 0.75	3.75 ± 0.33
HMP	Nonropy	8.5 ± 0.57	8.0 ± 0.22	8.30 ± 0.84	1.30 ± 0.08
	Ropy	8.0 ± 0.44	7.5 ± 0.31	6.42 ± 0.24	1.30 ± 0.56

Gelatin = 0.5%; CMC = 0.2%; HMP = 0.1%. Nonropy = (ST+LB); Ropy = Thermophilic culture YF-L811; Inoculation at 1% (w/v). Data are expressed as mean ± SE and were analyzed by SAS (t) test, one-way ANOVA followed by LSD test ($P \leq 0.05$).

Mouth coating

Mouth coating was significantly affected ($p < 0.05$) by culture selection and the type of stabilizer used (Table 3). Gelatin-stabilized yogurt with both non-ropy and ropy cultures recorded the highest mouth coating scores (9.0 and 8.0 points), followed by HMP-stabilized yogurt with both non-ropy and ropy cultures that mouth coating score was (8.0 and 7.5 points). CMC-stabilized yogurt with both non-ropy and ropy cultures had the lowest mouth coating score which recorded (5.5 and 3.0 points).

(8.30 and 6.42 points). CMC-stabilized yogurt with both non-ropy and ropy cultures had the lowest sourness score which recorded (5.72 and 4.28 points).

Off-flavors

As it shown in Table (3), off-flavors were minimal in both gelatin-stabilized and HMP-stabilized with both non-ropy and ropy cultures (1.35 and 1.16; 1.30 and 1.30 points, respectively); whereas, CMC-stabilized yogurt recorded the higher off-flavor scoring.

Sourness

The panelists gave their comments based on the tartness they felt in their mouth after tasting the yoghurt. The analysis of the sourness (Table 3) revealed that gelatin-stabilized yogurt with both non-ropy and ropy cultures recorded the highest sourness scores (9.38 and 7.14 points), followed by HMP-stabilized yogurt with both non-ropy and ropy cultures that sourness score was

Discussion

CMC stabilizer kept the acidity in constant value, that can explain synthetic stabilizer keep the buffering capacity in constant in both found ropy or nonropy cultures. Variation of protein content is related to the chemical structure of stabilizers used and evaluates its effect on the yogurt smoothies as aggregation of the protein which influence on the mouthfeel. Rheological and sensory properties of yoghurt may be

influenced by some technological factors, which mainly include specific properties of starter culture and addition of stabilizers (Rohm, 1993; Rohm & Schmidt 1993). Viscosity is a primary factor in the prevention of settling and the aggregation of solids suspended in drinks. Gelatin has ability to thicken or gel aqueous system of milk as gelatin-gelatin hydrogen bonded network (non-covalent bonding) whereas high methoxyl (HM) pectin molecules at low pH values is in negatively charged and the interaction with the positively charged casein micelles occurs to form a stable complex. Covalent linkage between protein and polysaccharide represents an attractive interaction may be weaker than gelatin-gelatin hydrogen bonded network whereas the protein in CMC-stabilized yogurt matrix was not maintained because yogurt gels had weaker protein networks. These effects on viscosity may influence the mouthfeel and other sensory characteristics.

Whey separation (wheying-off) is defined as the expulsion of whey from the network which then becomes visible as surface whey. Wheying-off negatively affects consumer perception of yogurt as consumers think there is something microbiologically wrong with the product. The lack of whey separation for the drinkable yogurt samples made with gelatin and HMP may indicate that there was a sufficient amount of negatively-charged hydrocolloid to provide repulsion on the positively-charged protein molecules of the yogurt, thereby stabilizing the matrix (Gaonkar, 1995). Shukla and Jain also found pectin and gelatin to be useful stabilizers to prevent whey separation (Shukla, & Jain, 1991) and several other researchers determined that gelatin reduces whey separation of yogurt (Jawalekar et al., 1993). More whey separation was in the drinkable yogurt samples made with CMC. The CMC formed complexes with the milk proteins as a result of charge neutralization between the positively charged protein and the negatively charged CMC (Hidalgo & Hansen, 1969) that precipitated out of solution. This was supported by others who found in yogurt made from buffalo milk (Shukla, & Jain, 1991). EPS decrease syneresis and improve product stability (De Vuyst, & Degeest, 1999). Similar results about the effect

of EPS on the reduction in syneresis of fermented skim milk have been reported by others (Marshall & Rawson, 1999; Amatayakul et al., 2006). This may be due to high water binding capacity of EPS and reduce permeability of serum through skim milk gel (Amatayakul et al., 2006).

Chalkiness, considered a defect in mouthfeel of some dairy systems, may be influenced by factors such as processing conditions, stabilizers, and starter culture selection (Maiolino, 2002 ; Wszolek et al., 2001). Sourness of gelatin-stabilized yogurts was very good. Yogurts fermented by the ropy cultures were perceived as being significantly ($p < 0.05$) less sour than those made from nonropy cultures. Off flavor caused by establish a relationship between increase proteolytic activity in milk and perception of bitter off flavor (Santos et al., 2003).

Gelatin-stabilized yogurt was highest smoothness. Chalkiness, a perceived defect of some dairy products, is an aspect of mouthfeel that is affected by the conditions associated with yogurt. Higher chalkiness (or lower smoothness) is related to larger visual particle size attributes.

Generally, mean scores for sensory mouth coating attributes were lower for drinkable yogurts made with ropy cultures and stabilized with all stabilizers than non-ropy cultures because yogurt gels had weaker protein networks. Sourness of yoghurt is derived from the various acids present in the yoghurt during fermentation. CMC-stabilized yogurt recorded higher off-flavor scoring since CMC was so different than the samples made with the other two stabilizers, this would account for a higher off-flavor scoring for this sample. Whereas, drinkable yogurt stabilized with gelatin was found to be the best overall for flavor and mouthfeel. These results suggest that the stabilizer choice influences the mouthfeel and other attributes of drinkable yogurt, depending on processing conditions and starter culture selection. Combination of stabilizer with exopolysaccharides has a considerable effect on the physiochemical properties and may be effective in improving the physical and rheological properties of drinkable yogurt (Zhang et al., 2012).

Conclusions

Both gelatin-stabilized and HMP-stabilized drinkable yogurts were more viscous and whereas yogurt using gelatin exhibits good mouthfeel characteristics, and less chalky than HMP-stabilized yogurts. These yogurt drinks also were the sourest, which agreed with the pH and titratable acidity data. Gelatin and HMP products were higher in protein content than CMC, as well. However, since the CMC-stabilized samples were so different from the other drinkable yogurts produced. Thus, better parallels can be drawn between the yogurts made with gelatin and HMP. This study showed significant differences were determined in viscosity, with the gelatin samples being thicker, regardless of the type of culture used for fermentation. Yogurt manufacturers used gelatin with both strains made the consistency arguably better and produce viscosity. Gelatin and HMP products were more effective than carboxymethylcellulose in preventing syneresis (separation) and have a beneficial influence on product stability and mouth-feel in drinkable yogurts. HMP-stabilized samples were found to be chalkier than those made with gelatin, though the chalkiness was not regarded as objectionable. Despite the sourness and chalkiness, drinkable yogurts produced with either stabilizer were found to be highly acceptable.

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