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Effect of Butternut Squash (*Cucurbita moschata*) Seed Powder on the Chemical and Rheological Properties of Stirred Cultured Camel Milk and Yoghurt

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Abstract

Research shows that producing fermented camel milk is hard because of the milk's inability to form a firm coagulum, attributed to low levels of *κ*-casein and *β*-lactoglobulin and the large casein micelle size, leading to a weak network of casein formation. In an effort to address this issue, researchers turned to corn starch as a thickening agent, discovering that a concentration of 2.0% effectively improved the viscosity and significantly reduced syneresis in stirred camel milk yoghurt and cultured camel milk. This study explores alternatives to corn starch, focusing on butternut squash seeds as a promising substitute due to their hydrocolloid composition. By incorporating butternut squash (*Cucurbita moschata*) seed powder (BSSP) as a thickening agent, this study aimed at enhancing the chemical and rheological properties of stirred camel milk yoghurt and cultured camel milk. Fermented camel milk was prepared using 4 litres of camel milk, 2% starter cultures (thermophilic culture for yoghurt and mesophilic aromatic culture for stirred cultured camel milk) and BSSP 0.0% (negative control), 0.4%, 0.8%, 1.2%, 1.6%, 2.0% mixed with 0.4% gelatin. 2.0% corn starch mixed with 0.4% gelatin was used as a standard for comparison. Results showed that increasing the BSSP level significantly ($p < 0.05$) decreased the moisture content while increasing the total solid content of stirred fermented camel milk products. There was an increase in ash content with an increase in BSSP levels. There was a significant ($p < 0.05$) reduction in the pH, with an increase in BSSP levels in stirred fermented camel milk samples. Increasing the concentration of BSSP from 0.4% to 2.0% resulted in a significant ($p < 0.05$) increase in viscosity and a reduction in syneresis of stirred camel milk yoghurt and stirred cultured camel milk samples. This study demonstrated that BSSP effectively enhances the viscosity, reduces syneresis and increases acidity in stirred fermented camel milk products during storage.

Keywords

Corn Starch, Butternut Squash Seed Powder, Gelatin, Stirred Camel Milk Yoghurt, Stirred Cultured Camel Milk

1. Introduction

The limited availability of processed camel milk products in Kenya can be attributed to technical challenges and low consumer receptiveness [1]. Camel milk's protein composition and colloidal structure differ significantly from those of bovine milk, causing processing challenges. These include instability during ultra-high temperature treatment, poor rennetability, weak curd formation, longer fermentation time and low thermal stability during drying [2]. Consequently, it is difficult to achieve the same viscosity in fermented camel milk products as is typically found in fermented bovine milk products that customers are accustomed to. Stirred fermented camel milk products are difficult to produce because camel milk does not coagulate well, resulting in a thin texture and frail product structure, with the gel texture being an important property in determining the mouthfeel, appearance and overall acceptability by consumers in the modern market with a shift in preference to a particular texture, such as thicker mouthfeel [3] [4]. The weak firmness of camel milk coagulum can be attributed to lack of κ-casein and β-lactoglobulin interactions [5], the large casein micelle size and low amounts of k-casein and high ratio of whey proteins to caseins, resulting in a fragile casein network that can easily be disrupted during coagulum formation [6].

Various dairy constituents (for example, whey protein concentrate) and hydrocolloids (for example, starch and various gums) have been utilized to combat defects in fermented milk like syneresis, poor body and texture [7]. Hydrocolloids are non-digestible carbohydrates that have the ability to form gels or viscous solutions, thickening, emulsifying, coating and stabilizing [8]. Hydrocolloids consist of lengthy and complex molecules that can either interconnect internally or with other molecules in their surroundings to create an emulsion. They are hydrophilic polymers that have many hydroxyl groups and may be polyelectrolytes [9]. These polysaccharides work by interacting with the casein network and contribute to the formation of gels in a two-phase system (liquid-solid); a continuous, solid, three-dimensional network structure forming the gel matrix holding finely dispersed liquid phase [10]. Addition of hydrocolloids maintains the morphological characteristics of yoghurt during transportation and storage by increasing its viscosity, absorbing water, and strengthening and improving its texture. They are derived from animals, plants, microorganisms, or synthetic origins and are naturally present in foodstuffs. Hydrocolloids extracted from various parts of plants include cellulose, pectin, starch and different gums like gum Arabic. Animal-based hydrocolloids encompass gelatin, casein, egg white protein and soy protein. Algae-derived hydrocolloids consist of agar, carrageenan and alginate while microbial-origin hydrocolloids include xanthan and dextran. Modified or semi-synthetic hydrocolloids include methylcellulose, ethylcellulose, carboxymethyl cellulose and propylene glycol alginate [8]. There is a rising need for hydrocolloids because of their capacity to create a stable emulsion system in dairy products, preventing whey separation and protein clumping throughout their shelf life [11]. Through various mechanisms like covalent, electrostatic, excluded volume, hydrophobic interactions, and van der Waal forces, hydrocolloids combine with milk proteins to establish a gel network system, thereby enhancing the texture of dairy items [12] [13]. Only a small portion of Butternut squash is utilized directly for human consumption whereas the remaining portion (skin and seeds) is undervalued and treated as by-products and waste. These wastes can make important and valuable contributions to food resources and development of industrial products considering the abundant nutrition and technological properties contained in these residues [14]. A major issue encountered by many nations is handling waste, especially from food products and agricultural produce. These wastes have a significant global environmental impact due to their biodegradable nature and high-water content contributing to pollution and have the potential to produce bad odour, abundant leachate [15] and emit greenhouse gases (for example, methane) in landfills [16].

Butternut seeds boast a rich nutrition profile, featuring lipids, proteins, vitamins, phytosterols, minerals such as potassium, calcium and sodium and trace elements [17] [18]. Specifically, butternut squash seeds have a protein content of 32.38%, a fat content of 14.31% and a total phenolic content of 1.82 ± 0.05 mg GAE/g [14]. It also contains a fibre content of 1.152 ± 0.20% and ash content of 1.152 ± 0.20% [19]. [20] obtained polysaccharides from defatted butternut squash seed powder, the yield of crude polysaccharides was 2.3 %. Hydrocolloids from Butternut squash (*Cucurbita moschata*) seeds were evaluated as a stabilizer to preserve the physicochemical properties, flavour and texture of yoghurt samples. The addition of hydrocolloids from butternut squash seeds modified the rheology with positive effects on the texture, and improved the physical stability and overall mouthfeel properties to increase desirable sensorial attributes without any consequent appearance of undesirable effects [21]. The researchers concluded that hydrocolloids from butternut squash seeds could be used as an additive for the formulation of microstructure food matrices. It can be utilized alone or blended with other hydrocolloids to increase viscosity or thickness and improve the water-binding ability and texture of yoghurt.

There have been several attempts to remedy these challenges facing production of stirred fermented camel milk products. The reported approaches include using different gelling and thickening agents either alone or together (for example gelatin, corn starch, modified starch, bovine skim milk powder, polymerized whey protein isolate), hydrocolloids (for example xanthan gum, pectin, gum Arabic, alginate, gum acacia carboxymethyl cellulose, κ-carrageenan, sodium carboxymethyl cellulose) and other stabilizers such as calcium chloride Na_2EDTA and mono- and di-glyceride [5] [22]-[30].

This study examined how varying concentrations (0.4%, 0.8%, 1.2%, 1.6%, and 2.0%) of BSSP affected the chemical composition of both stirred camel milk yoghurt and stirred cultured camel milk. The rheological characteristics of stirred camel milk yoghurt and stirred cultured camel milk were also studied for the 21 days of storage at 1, 7, 14, and 21 days intervals. Two controls were employed for this experiment; the negative control consisting of camel milk mixed with 0.4% gelatin and a standard consisting of camel milk mixed with 2.0% corn starch and 0.4% gelatin.

2. Materials and Methods

2.1. Sample Collection

Fresh camel milk was procured from Marigat, Baringo County, Kenya. Fresh raw camel milk was conveyed in clean 20-litre plastic jerricans to the Department of Dairy and Food Science and Technology, Egerton University, Nakuru City, Kenya. Gelatin powder (beef skin), and corn starch (Tri-Clover Industries Kenya Limited) were all procured from Gilanis supermarket, Nakuru city, Kenya. Starter cultures (thermophilic and mesophilic) were procured from Promaco Kenya Limited. Whole butternut squash seeds were obtained from Vegpro Kenya Limited, Nairobi City, Kenya.

2.2. Preparation of Butternut Squash (*Cucurbita moschata*) Seeds

Fresh butternut squash seeds were collected from Vegpro Kenya Limited during butternut squash processing, cleaned with distilled water and then oven-dried at 65˚C for 12 hours as described by [14]. The seeds were then powdered using a hammer mill and subsequently sieved using a no. 30 sieve (600 μm) in size to remove any coarse particles. Powdered butternut squash seeds were stored in zip-lock bags until use.

2.3. Preparation of Stirred Fermented Camel Milk Products

Prior to making of stirred fermented camel milk products, all equipment was carefully cleaned and sterilized using hot water. Different formulations were employed to produce stirred fermented camel milk products; this was achieved by altering the concentrations of BSSP (0.4%, 0.8%, 1.2%, 1.6%, 2.0%), while maintaining the concentration of gelatin at 0.4%. Fresh camel milk mixed with 0.4% gelatin was utilized as the negative control and fresh camel milk mixed with 2.0% corn starch and 0.4% gelatin as the standard. Stirred fermented camel milk products (yoghurt and stirred cultured camel milk) were produced using steps outlined by [29] [30] but with minor changes. For stirred camel milk yoghurt samples, raw camel milk was preheated to 65˚C to facilitate addition of dry ingredients (stabilizers). The mixture was then pasteurized in a thermostatically controlled water bath at 85˚C for 30 minutes and then allowed to cool to 45˚C to facilitate inoculation of thermophilic yoghurt culture (Chr Hansen, YF-L903, Denmark) which consisted of strains of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophillus*. Incubation was then carried out at 45˚C for 6h and refrigerated at 4˚C until the samples were analyzed. For stirred cultured camel milk samples, raw camel milk was preheated to 65˚C to facilitate addition of dry ingredients (stabilizers). The mixture was then pasteurized at 85˚C for 30 minutes. The pasteurized mixture was then cooled to 25˚C to facilitate inoculation of mesophilic aromatic culture (Chr Hansen, CHN-22, Denmark), which consisted of strains of *Lactococcus lactis* subsp. *Cremoris, Leuconostoc*, *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *lactis biovar diacetylactis*. Fermentation was carried out at 25˚C for 24 h.

2.4. Chemical Properties

2.4.1. Determination of Total Solid Content

The weight of the residue obtained from analysis of moisture content in stirred fermented camel milk samples was used to calculate the total solids using the formula described by Association of Official Analytical Chemists (AOAC, 2005, Method 925.23), as shown in Equation (1):

$$\text{Total Solids}(\%) = \frac{\text{dry sample}}{\text{weight of the sample}} \times 100 \quad (1)$$

2.4.2. Determination of Ash Content

The ash content of the stirred fermented camel milk products was determined following the AOAC (2005 Method number 930.05). 10 g of stirred fermented camel milk samples were weighed and transferred to a dry crucible. The samples were subjected to charring using a flame to decompose all organic components. Subsequently, the samples were ashed in a muffle furnace and incinerated at 550˚C for 6 h and cooled in a desiccator for 10 mins, the samples were weighed, and the ash content was calculated using the formula in Equation (2):

$$\text{Ash}(\%) = \frac{\text{weight of residue}}{\text{weight of sample}} \times 100 \quad (2)$$

2.4.3. Determination of pH

The pH of fermented camel milk products was determined using a pH meter (Adwa Instruments, Model 1020, Szeged, Hungary). The meter was calibrated using standard buffer solution of pH 4.0 and pH 7.0 and rinsed with distilled water.

2.5. Rheological Properties

2.5.1. Measurement of Syneresis

Gelled fermented camel milk product (10 ml) was centrifuged at 3000 rpm for 10 minutes at 10˚C according to [29] with slight modifications. The syneresis of fermented camel milk products was determined at 1, 7, 14, and 21 days. Measurement of susceptibility to syneresis was determined using the formula in Equation (3):

$$\text{Syneresis}(\%) = \frac{\text{Volume of separated whey}}{\text{10 ml offer mented camel milk product}} \times 100 \quad (3)$$

2.5.2. Measurement of Viscosity

The viscosity of fermented camel milk products was determined at 10˚C for yoghurt and 20˚C for cultured camel milk using DVELV viscometer (Brookfield Ametek, Model LV, Middlesboro, USA). Spindle no. 63 and 20 rpm (rotation speed) were used to measure 500 ml of fermented camel milk products.

2.6. Data Analysis

Data analysis was carried out using Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.4 and Microsoft Excel (Version 2016). To test the study hypothesis, analysis of variance (ANOVA) was performed. The level of significance was established at $p < 0.05$ confidence level and means separation was done using Tukey's Honestly significant difference (HSD) method.

3. Results and Discussions

3.1. Effect of BSSP on the Chemical Properties of Stirred Fermented Camel Milk Products

3.1.1. Total Solid Content

The total solid content values for stirred camel milk yoghurt samples ranged from 10.90% to 15.78% as shown in (**Table 1**), whereas stirred cultured camel milk samples ranged from 11.03% to 14.67% as shown in (**Table 2**). Addition of BSSP significantly ($p < 0.05$) increased the total solids content of stirred camel milk yoghurt samples and stirred cultured camel milk samples with 2.00% BSSP and 2.00% corn starch (standard) as a thickening agent having the highest values. Also, it was apparent that increasing BSSP concentration from 0.4% to 2.0 % significantly ($p < 0.05$) decreased moisture content in stirred fermented camel milk products, conversely increasing the total solids. This could be attributed to the fact that BSSP contained hydrocolloids. Hydrocolloids are hydrophilic in nature and are effective in absorbing water by physically trapping free water and confining them in the increased network density and chemically by facilitating a link with other water molecules, thus increasing the gel-water binding capacity [9] [31]. Total solids content is a significant factor in the determination of the viscosity and rheological characteristics of yoghurt. Studies have indicated that higher total solid solids may result in improved viscosity, thus positively impacting the quality of yoghurt [32]. Total solids are the most important technological property that determines the physical stability of yoghurt gel structure. Insufficient total solids fortification leads to wheying off and weak body [33].

The average total solid content values reported by other researchers are as follows: 16.65% [23], 12.2% [34], 9.24% [35], and 11.83% [36].

Table 1. Chemical composition of stirred camel milk yoghurt.

Parameter	Negative control	0.4% BSSP	0.8% BSSP	1.2% BSSP	1.6% BSSP	2.0% BSSP	2.0% corn starch (standard)
Moisture (%)	$89.10^{a} \pm 0.03$	$85.93^{b} \pm 0.03$	$85.64^{c} \pm 0.01$	$85.47^{d} \pm 0.01$	$85.08^{e} \pm 0.01$	$84.22^{g} \pm 0.01$	$84.63^{f} \pm 0.02$
Total solids (%)	$10.90^{g} \pm 0.03$	$14.07^{f} \pm 0.03$	$14.36^{e} \pm 0.01$	$14.53^{d} \pm 0.01$	$14.92^{c} \pm 0.01$	$15.78^{a} \pm 0.01$	$15.37^{b} \pm 0.02$
Ash (%)	$0.23^{f} \pm 0.00$	$0.46^{e} \pm 0.02$	$0.63^{d} \pm 0.02$	$0.71^{d} \pm 0.00$	$0.80^{c} \pm 0.03$	$1.08^{a} \pm 0.06$	$0.94^{b} \pm 0.00$

Note: Values are means ± SE. Different superscript letters within the same row showed significant differences between the samples ($p < 0.05$).

Table 2. Chemical composition of stirred cultured camel milk.

Parameter	Negative control	0.4% BSSP	0.8% BSSP	1.2% BSSP	1.6% BSSP	2.0% BSSP	2.0% corn starch (standard)
Moisture (%)	$88.97^{a} \pm 0.01$	$86.36^{b} \pm 0.08$	$85.95^{c} \pm 0.02$	$85.85^{dc} \pm 0.01$	$85.74^{d} \pm 0.03$	$85.33^{e} \pm 0.02$	$85.48^{e} \pm 0.01$
Total solids (%)	$11.03^{e} \pm 0.01$	$13.64^{d} \pm 0.08$	$14.05^{c} \pm 0.02$	$14.15^{cb} \pm 0.01$	$14.26^{b} \pm 0.03$	$14.67^{a} \pm 0.02$	$14.52^{a} \pm 0.01$
Ash (%)	$0.230^{g} \pm 0.00$	$0.420^{f} \pm 0.01$	$0.521^{e} \pm 0.02$	$0.622^{d} \pm 0.00$	$0.706^{c} \pm 0.01$	$0.953^{a} \pm 0.02$	$0.844^{b} \pm 0.01$

Note: Values are means ± SE. Different superscript letters within the same row showed significant differences between the samples ($p < 0.05$).

3.1.2. Ash Content

The ash content values varied from 0.23% to 1.08% for stirred camel milk yoghurt as shown in (Table 1) and 0.23% to 0.953% for stirred cultured camel milk as shown in (Table 2). Addition of BSSP as a thickening agent significantly ($p < 0.05$) increased the ash content of both stirred camel milk yoghurt and stirred cultured camel milk. Stirred camel milk yoghurt sample containing 2.0% BSSP and stirred cultured camel milk sample containing 2.0% BSSP had the highest percentage of ash content compared to other samples indicating that 2.0% BSSP is rich in minerals compared to corn starch when used as a thickening agent at the same concentration. Ash content is of significant importance as it serves as an indicator of the mineral composition within the product, thus contributing to its nutritional value and potential health benefits. The average ash content values reported by other researchers are as follows: 0.99% [3], 1.13% [23], 0.71% [34], and 0.84% [36].

3.2. Effect of BSSP on the Storage of Stirred Fermented Camel Milk Products

3.2.1. pH

During storage, different treatments of BSSP had significant ($p < 0.05$) effects on both stirred camel milk yoghurt and stirred cultured camel milk pH. During storage, the pH of the negative control in stirred camel milk yoghurt decreased from 5.02 to 4.88. The pH of the stirred camel milk yoghurt sample containing 2.0% corn starch decreased from 4.8 to 4.72. Samples treated with different concentrations of BSSP also decreased; the pH of the yoghurt sample containing

0.4% BSSP decreased from 4.81 to 4.70; the pH of the stirred camel milk yoghurt sample containing 0.8% BSSP decreased from 4.79 to 4.66; the pH of the stirred camel milk yoghurt sample containing 1.2% BSSP decreased from 4.77 to 4.61; the pH of the stirred camel milk yoghurt sample containing 1.6% BSSP decreased from 4.62 to 4.43; the pH of the stirred camel milk yoghurt sample containing 2.0% BSSP decreased from 4.59 to 4.40 after being stored for 21 days (**Figure 1**). In the case of stirred cultured camel milk, the pH of negative control decreased from 4.78 to 4.69. The pH of the stirred cultured camel milk sample containing 2.0% corn starch decreased from 4.69 to 4.60. Samples treated with different concentrations of BSSP decreased; the pH of the stirred cultured camel milk sample containing 0.4% BSSP decreased from 4.68 to 4.59; the pH of the stirred cultured camel milk sample containing 0.8% BSSP decreased from 4.67 to 4.55; the pH of the stirred cultured camel milk sample containing 1.2% BSSP decreased from 4.65 from 4.53; the pH of the stirred cultured camel milk sample containing 1.6% BSSP decreased from 4.62 to 4.51; the pH of the stirred cultured camel milk sample containing 2.0% BSSP decreased from 4.6 to 4.49 after being stored for 21 days (**Figure 2**). The continuous decrease in pH values could be attributed to conversion of lactose to lactic acid by lactic acid bacteria during fermentation and the subsequent storage period (1 - 21 days) [22] [25] [30] [37] [38]. The decrease in pH can also be attributed to the ability of BSSP to retain water since it contains fibre thereby diluting the concentration of lactic acid and other organic acids produced by the starter cultures [39]. There are several factors that can also reduce the pH of fermented milk including total soluble solids, additives and storage temperature [40].

Increasing the concentration of BSSP from (0.4% to 2.0%), reduced the pH values in both stirred camel milk yoghurt and stirred cultured camel milk samples as shown in **Figure 1** and **Figure 2**. There was a progressive decrease in pH

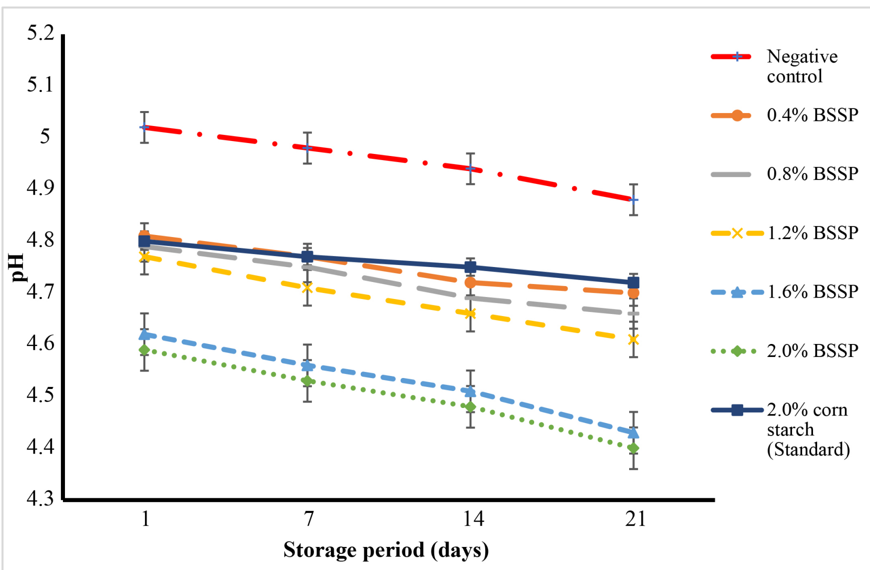

Figure 1. Effect of BSSP on stirred camel milk yoghurt formulations during storage.

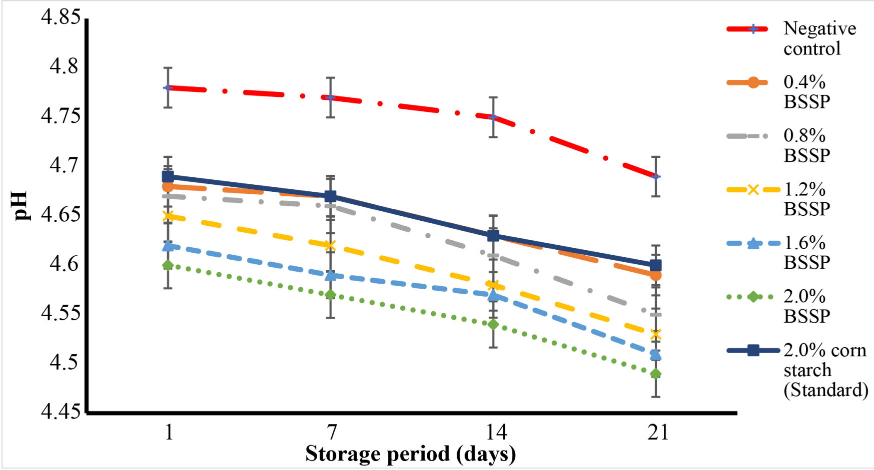

Figure 2. Effect of BSSP on the pH of stirred cultured camel milk formulations during storage.

values for all stirred camel milk yoghurt samples and stirred cultured camel milk samples but the pH decrease for stirred camel milk yoghurt samples containing 2.0% BSSP and stirred cultured camel milk sample containing 2.0% BSSP was significantly higher ($p < 0.05$) than the negative control samples in both stirred camel milk yoghurt and stirred cultured camel milk samples. This could be due to the higher total solids content in stirred camel milk yoghurt samples containing 2.0% BSSP and stirred cultured camel milk samples containing 2.0% BSSP that may have hindered the movement of the liquid phase and influenced the activities of starter cultures to metabolize sugars, producing lactic acid and organic acids as the main metabolic end products [23] [30] [41].

These findings exhibited comparable trends to those observed by other researchers including; [25] [30]. The pH of stirred camel milk yoghurt decreased with increasing fermentation time from 0 - 6 hours and storage time from 1 to 21 days. The negative control yoghurt sample experienced a reduction in pH levels from 6.68 to 4.47 within a span of 6 hours, further declining to 4.4 after a period of 21 days. All stirred camel milk yoghurt samples treated with stabilizers decreased in their pH values after 21 days of storage [30]. The pH values of stirred camel milk yoghurt samples varied based on the type and amount of stabilizer added. Stabilizers caused a decrease in pH compared to the control samples, with the highest acidity observed in the stabilizer-treated stirred camel milk yoghurts. The decline in pH over time during storage was attributed to continued fermentation by lactic acid bacteria and the acidity contributed by the added stabilizers. This decline was more pronounced in stirred camel milk yoghurt containing stabilizers compared to the control [25].

3.2.2. Syneresis

All stirred camel milk yoghurt samples and stirred cultured camel milk samples had a significant ($p < 0.05$) decrease in their syneresis percentage in comparison to the negative control samples that did not contain any thickening agent in stirred camel milk yoghurt and stirred cultured camel milk samples, indicating that combining gelling agents and thickening agents reduced susceptibility to syneresis of both stirred camel milk yoghurt and stirred cultured camel milk samples. Combining both gelling and thickening agents improves the texture of fermented milk texture by promoting coagulum formation and because of the solubilization ability of gelatin, it increases the intermolecular interactions with the thickening agents, improving the viscosity and holding the gels together reducing syneresis [29].

During storage, the susceptibility to syneresis of the yoghurt control sample increased from 92.5% to 94.7%; stirred camel milk yoghurt sample containing 0.4% BSSP increased from 42.2% to 75.8%; stirred camel milk yoghurt sample containing 0.8% BSSP increased from 30.3% to 65.2%; stirred camel milk yoghurt sample containing 1.2 % BSSP increased from 21.3% to 60%; stirred camel milk yoghurt sample containing 1.6% BSSP increased from 13.5% to 53.7%; stirred camel milk yoghurt sample containing 2.0 % BSSP increased from 1.2% to 49%; standard stirred camel milk yoghurt sample containing 2.0% corn starch increased from 0 to 42.8% after being stored for 21 days. As for stirred cultured camel milk susceptibility to syneresis increased during storage, the control sample increased from 91.3% to 95.3%; the stirred cultured camel milk sample containing 0.4% BSSP increased from 39.8% to 73.8%; the stirred cultured camel milk sample containing 0.8% BSSP increased from 29% to 65.8%; the stirred cultured camel milk sample containing 1.2% BSSP increased from 21% to 60.3%; the stirred cultured camel milk sample containing 1.6% BSSP increased from 16% to 52.7%; the stirred cultured camel milk sample containing 2.0% BSSP increased from 2.5% to 48.7%; the standard stirred cultured camel milk sample containing 2.0% corn starch increased from 0% to 43.2% after being stored for 21 days. Susceptibility to syneresis was significantly ($p < 0.05$) reduced with increase in concentration of BSSP from 0.4% to 2.0%. This can be explained by the highly branched structure of BSSP, which could easily interact with gelatin and form bonds with the protein matrix in camel milk and ions in aqueous phase and water [21]. These current results corroborate the findings of [4] [21] [29] [30] who reported that increasing the concentration of stabilizers, using both gelling and thickening agents reduced syneresis. The decrease in syneresis of samples containing BSSP may also be attributed to gummy sugars in fibres, which can trap water. These findings also align with the outcomes reported by [42] for yoghurt containing flaxseed press cake and [39] for yoghurt containing date press cake.

In summary, stirred camel milk yoghurt sample containing 2.0% BSSP and 2.0% corn starch and 2.0% BSSP and 2.0% BSSP in stirred cultured camel milk sample displayed significantly ($p < 0.05$) lower syneresis percentage over the storage period (1 - 21 days) because of the higher concentration of thickening agents as compared to all the other stirred camel milk yoghurt and stirred cultured camel milk formulations. The negative control samples in both stirred camel milk yoghurt and stirred cultured camel milk samples exhibited high syneresis percentage over the storage period (1 - 21 days). It was worth noting that there was a sharp increase in syneresis percentage on day 21 of storage in all the stirred camel milk yoghurt and stirred cultured camel milk samples as illustrated in Figure 3 and Figure 4. This could be attributed to reduction in total solids content over the storage period due to breakdown of macromolecules [33].

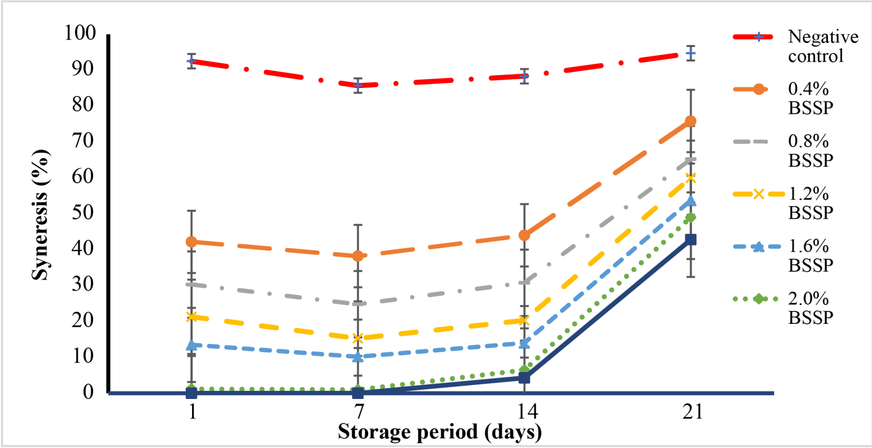

Figure 3. Effect of BSSP on the syneresis of stirred camel milk yoghurt during storage.

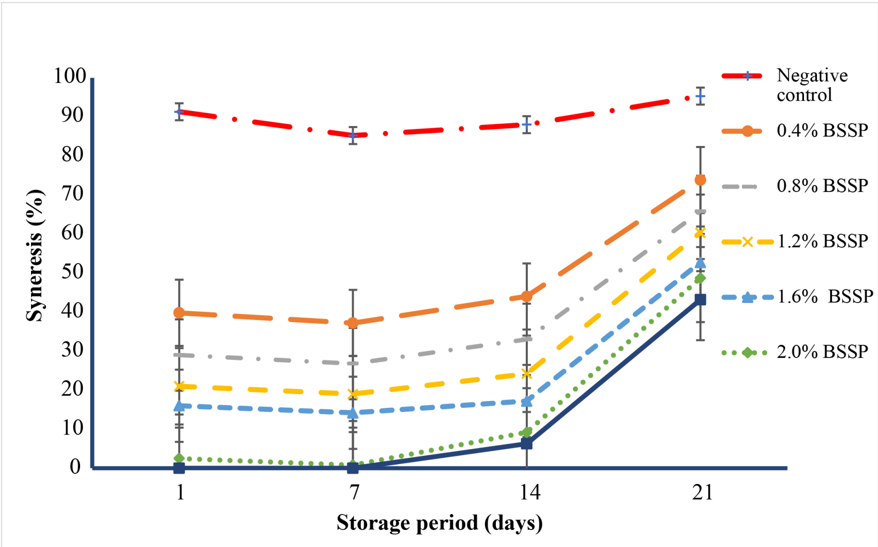

Figure 4. The effect of BSSP on the syneresis of stirred cultured camel milk formulations.

3.2.3. Viscosity

The viscosity values of stirred camel milk yoghurt and stirred cultured camel milk samples increased from day 1 to day 7 of storage, followed by a decline on day 14 and a sharp drop on day 21 of storage. There was no significant difference between the standard and stirred camel milk yoghurt sample containing 2.0% BSSP and stirred cultured camel milk sample containing 2.0% BSSP but the standard had the highest viscosity values compared to BSSP when used as a thickening agent at the same concentration. This could be attributed to the gel-forming characteristics of corn starch that prompted interactions between casein micelles in camel milk and corn starch [23] [30] [41] and the difference in structure between BSSP and corn starch polysaccharide. The standard exhibited better and increased intermolecular associations forming stronger junction zones with gelatin that facilitated better gel reformation contributing to an increase in viscosity and reduced susceptibility to syneresis as compared to 2.0% BSSP mixed with 0.4% gelatin. It was worth noting that increasing the concentration of BSSP from (0.4% to 2.0%) significantly ($p < 0.05$) increased the viscosity of both stirred camel milk yoghurt and stirred cultured camel milk during storage. This is because low levels of BSSP did not cover and interact with all the casein particles in camel milk to create sufficient electrostatic and steric repulsions to stabilize the dispersion but higher concentrations of BSSP could sufficiently interact with the casein micelles hence the higher viscosity values. The addition of hydrocolloids from butternut squash seeds influenced the viscoelastic parameters of the yoghurt, with significant differences observed in G′ and G″ values among samples containing hydrocolloids from butternut squash seeds. The frequency sweep results revealed changes in the gel-like behaviour of the yoghurt samples, with hydrocolloids from butternut squash seeds contributing to the formation of a strong gel structure and interacting with milk proteins [21].

During storage, the viscosity values significantly ($p < 0.05$) decreased from the day of processing to the end of storage. In stirred camel milk yoghurt, the viscosity of the negative control sample containing 0.4 % gelatin solely decreased from 34 cP to 26 cP; the viscosity of the stirred camel milk yoghurt sample containing 0.4% BSSP decreased from 179 cP to 85 cP; the viscosity of the stirred camel milk yoghurt sample containing 0.8% BSSP decreased from 422 cP to 221 cP; the viscosity of the stirred camel milk yoghurt sample containing 1.2% BSSP decreased from 619 cP to 362 cP; the viscosity of the stirred camel milk yoghurt sample containing 1.6% BSSP decreased from 827 cP to 443 cP; the viscosity of the stirred camel milk yoghurt sample containing 2.0% BSSP decreased from 1076 cP to 676 cP; the viscosity of the standard sample containing 2.0% corn starch decreased from 1404 cP to 850 cP after being stored for 21 days (**Figure 5**). As for stirred cultured camel milk, the viscosity of the negative control sample containing 0.4% gelatin solely decreased from 50 cP to 32 cP; the viscosity of the stirred cultured camel milk sample containing 0.4% BSSP decreased from 147 cP to 87 cP; the viscosity of the stirred cultured camel milk sample containing 0.8% BSSP decreased from 431 cP to 249 cP; the viscosity of the stirred cultured camel milk sample containing 1.2% BSSP decreased from 602 cP to 365 cP; the viscosity of the stirred cultured camel milk sample containing 1.6% BSSP decreased from 784 cP to 438 cP; the viscosity of the stirred cultured camel milk sample containing 2.0% BSSP decreased from 957 cP to 577 cP; the viscosity of the standard sample containing 2.0% corn starch decreased from 1282 cP to 739 cP following 21 days of storage (**Figure 6**).

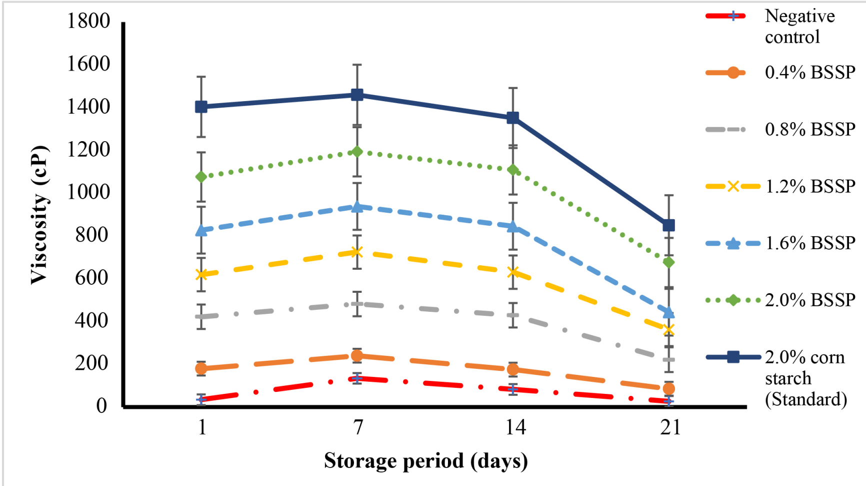

Figure 5. The effect of BSSP on the viscosity of stirred camel milk yoghurt formulations.

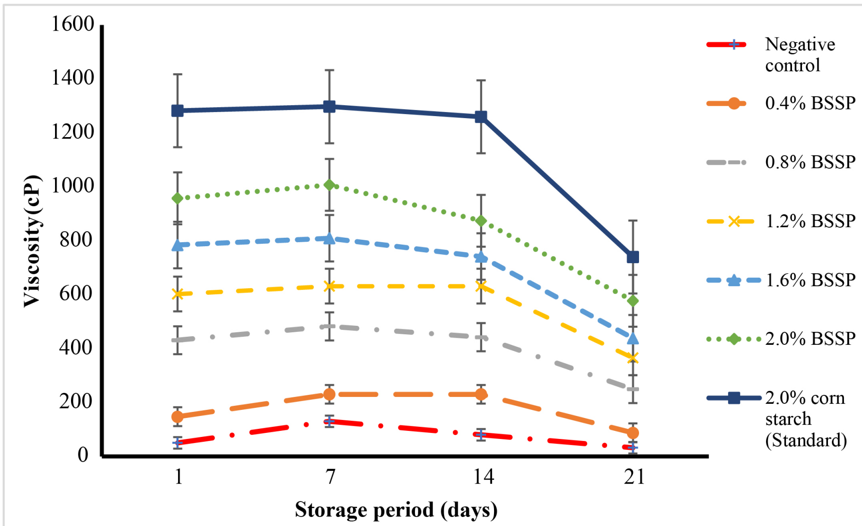

Figure 6. The effect of BSSP on the viscosity of stirred cultured camel milk formulations.

From the results of the present study there was significant ($p < 0.05$) difference in stirred camel milk yoghurt and stirred cultured camel milk samples containing thickening agents and the negative control samples containing only a gelling agent indicating the important role played by thickening agents in improving and increasing the viscosity of stirred fermented camel milk products. Viscosity was low in gels formed with either gelatin or corn starch alone but combining both gelling and thickening agents improved the viscosity and reduced syneresis of stirred fermented camel milk products [29]. These findings exhibited similar trends with those observed by other researchers reporting that increasing concentrations of stabilizers, increased viscosity [4] [21] [25] [29] [30]. BSSP also contains fibre and several studies have also indicated that fortifying yoghurt with various dietary fibres enhances the viscosity and thickening characteristics of fermented milk [39] [43] [44].

Incorporating hydrocolloids sourced from butternut squash seeds as a stabilizer resulted in a decrease in apparent yield stress across all yoghurt samples, indicating intensified crosslinking of milk proteins in acidified milk, thereby impacting the yoghurt's structure under shear conditions. Research has shown that yoghurt samples exhibited non-Newtonian flow behaviour, whereas the apparent viscosity decreased as the shear rate increased, indicating shear-thinning tendency. The decrease in viscosity with increasing shear rate was attributed to the aligned flow of stiff polymer molecules, which reduced interactions between adjacent polymer molecules, which reduced interactions between adjacent polymer chains and disrupted the casein micelle network during shear application. Yoghurt samples containing hydrocolloids showed a two-step yield stress, indicating changes in the structural properties of the yoghurt matrix. The activation energy values of the yoghurt samples increased with the addition of hydrocolloids suggesting a higher temperature dependence of viscosity in samples with higher hydrocolloid content [21].

4. Conclusion

This study demonstrates the promising potential of utilizing discarded butternut squash (*Cucurbita moschata*) seeds as a thickening agent in the development of stirred thermophilic and mesophilic fermented camel milk thus yoghurt and cultured milk respectively. The inclusion of BSSP in stirred cultured camel milk and yoghurt samples resulted in a significant ($p < 0.05$) reduction in syneresis values and an increase in viscosity values compared to the control. Moreover, higher concentrations of BSSP proved to be effective in further enhancing viscosity and reducing syneresis in these products. The incorporation of BSSP emerges as a viable and sustainable alternative, not only contributing to waste reduction by utilizing butternut squash seeds, but also offering tangible benefits in terms of texture improvement in stirred fermented camel milk products. These results present an opportunity for the food industry, particularly those involved in the production of stirred fermented camel milk products, to consider innovative approaches for enhancing product quality and consumer satisfaction.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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