Production and Quality Evaluation of Cheese from Soy and Coconut Milk Using Selected Coagulants

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cheese was produced from soy milk, cow milk and coconut milk using lime, lemon and rennet as coagulants. The effect of these coagulants on proximate composition, coagulation time, percentage yield, peroxide value, Thiobarbituric Acid Reactive Substance (TBA-RS), micro-biological and sensory qualities of the formulated cheese was evaluated using standard methods. Nine samples were designed for this study. The moisture content of rennet coagulated cheese was significantly higher than lime and lemon coagulated cheese, while the protein content of lime coagulated cheese was significantly ($p < 0.05$) lower than those of lemon and rennet coagulated cheese. The crude fat and total ash contents of cheese made from cow milk were superior to those

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made from soy milk and coconut milk. The fibre content of lime coagulated cheese was significantly (p < 0.05) higher than lemon and rennet coagulated cheese. The coagulation time and percentage yield of the cheese samples did not follow a definite trend and ranged between 19-147 sec and 12.40-28.70% respectively. Aside samples D_{SL} and H_{CL}, all the other freshly prepared cheese samples fell within the standard value of 10 mEq/kg. However, with an increase in storage time, virtually all the samples became rancid. With an increase in storage time. Similar trend was observed in the TBA-RS of the cheese samples. All the samples were microbiologically safe for human consumption and the cheese samples were organoleptically acceptable, since their sensory scores were above average. The study established that cheese produced from fresh cow milk, soy milk and coconut milk coagulated with lime, lemon and rennet showed to a large extent significant differences in their chemical composition, percentage yield and coagulation time. The peroxide value and TBA-RS determination from this study showed that the cheese could not stay longer than a day on the shelf, unless it is refrigerated.

1. INTRODUCTION

Cheese is a concentrated dairy produced by acid or rennet coagulation or curdling milk, stirring and heating the curd, draining off the whey, collecting and pressing the Curd [1] and the cheese is ripened, cured, or aged to develop the flavour and texture. Cheese is made most commonly from pasteurized cow milk, but the milk of other mammals may be used. Cheese production is common to households in many developing countries, which provides a useful service in increasing the shelf-life of valuable human food- stuff like milk [2]. In Nigeria, milk production is mainly practised by the Fulani nomadic people who are pastoralists involved in the rearing of cattle and moving from one location to another in search of green pasture. Due to lack of refrigeration facilities, the Fulani women process the surplus fresh milk into a soft, un-ripened Cheese called "*Warankasi*" or "*Wara*" [3].

The principle of cheese processing is based on the coagulation of the protein in milk, during which about 90% of the milk fat is entrapped [4]. The coagulated mass is the curd; while the remaining liquid is called whey [4]. Curd (cheese) consists mainly of milk proteins (casein) and milk fat; while whey mainly contains water, milk sugar (lactose), protein (serum proteins) and B vitamins [5]. In many parts of tropical Africa, milk and milk products are scarce and unaffordable by majority of the populace [6]. The high and unaffordable cost of milk in some developing countries like Nigeria has made it necessary to source for less expensive plant products that could be used as substitutes for milk products or to augment the use of milk products for effectiveness in fighting protein malnutrition [7]. Milk can be extracted from soybeans and other legumes which offer very cheap sources of vegetable milk, and could be used as substitutes for whole milk from animal sources in the production of cheese curds.

Soy milk, sometimes called soy drink or soy beverage, is a white emulsion which resembles cow milk (conventional milk) in both appearance and consistency [8]. Milk from soybean provides malnourished infants as well as individuals who suffer from cow milk associated allergies with an alternative. There is increasing interest among nutritionists in considering soy milk as a potential substitute for cow milk and human milk. Soy milk is reported to have great potentials to supplement cow milk, as it contains high quality protein and essential amino acids; essential minerals and vitamins [9]. Soy milk contains phytochemicals that have anti-tumor activity and prevent cancer; high blood pressure and cardiovascular diseases [9].

Coconut has a good reserve of fibre which aids digestion. It is an excellent substitute for cow milk for the development of cheese-like products. Coconut milk is the liquid that comes from the grated meat of a brown coconut [1]. It has no cholesterol, contains many vitamins, minerals and electrolytes, including potassium, calcium and chloride [1].

This study was designed to assess the comparative effects of using lime, and lemon as plant based coagulants in place of rennet in formulating cheese from soy, and coconut milk, when compared with that of cow. The physico-chemical properties, coagulation time, cheese yield, peroxide value, Thiobarbituric Acid Reactive Substance (TBA-RS), microbiological

quality, and sensory attributes of the samples were evaluated.

2. MATERIALS AND METHODS

2.1 Source of Materials

The raw materials such as fresh cow milk, coconut, soybean, lime and lemon were procured from Wadata Market in Makurdi, Benue State, North-Central Nigeria, while the rennet was bought from Goat Nutrition Limited, United Kingdom.

2.2 Sample Preparation

2.2.1 Production of coconut milk

Coconut milk was produced following the method described by [1] with slight modification. 3 kg of coconut was purchased, shelled, washed and shredded using a traditional coconut grater. Coconut milk was produced by mixing the shredded pulp with an equal weight of warm distilled water (60 °C) in a blender, filtered through a double-layered cheese cloth, and manually squeezed with a twisting motion to extract most of the milk. The extracted emulsion was pasteurized and stored at 30°C before the production of cheese, and which occurred within 24 h of production.

2.2.2 Production of soy milk

Soy milk was produced using the method described by [10] with some modification. Briefly, 2 kg of soybean seeds were cleaned, sorted and soaked for 12 h. The rehydrated soybeans were dehulled by rubbing between palms and the hulls were drained away in excess water by the process of water floatation. Four cups of water was added to the dehulled soybeans and blended in a blender until it became smooth. The slurry was strained using a muslin cloth. The recovered milk was boiled for about 20 min at 82 °C in stainless steel pan, while stirring continuously with a wooden stirrer to prevent it from burning. The milk was homogenized using a blender and cooled to 45°C.

2.2.3 Preparation of juice extracts

Lime and lemon were cut into two halves, and the juice was squeezed out and filtered using muslin cloth.

2.2.4 Preparation of the cheese

Cheese was produced using the method described by [11]. Briefly, raw fresh cow milk, coconut milk and soy milk (one litre each) were placed inside stainless steel pots separately. Each of the milk samples was heated on a magnetic stirrer until they boil. On boiling, 5 mL each of the coagulants (lime, lemon and rennet) were added every 5 min to the boiling milk. Heating of the milk continued until curds were formed inside the pots. The pots were then removed from the heat source, cooled inside a water bath for 15 min, then drained using Muslin cloth to remove the whey. The curds (Cheese) were then packaged and refrigerated for further analysis.

2.3 Analyses

2.3.1 Determination of proximate composition

The moisture, crude protein, crude fat, crude fibre and total ash contents of the milk and cheese samples were determined according to the standard methods of AOAC [12]. The carbohydrate content was determined as shown below:

% Carbohydrate = 100% − (% moisture + % protein + % fat + % crude fibre+ % ash) [13].

2.3.2 Determination of physico-chemical properties

The specific gravity of the milk samples was determined according to the method described by [14].Total Titratable Acidity was determined by the method of AOAC [12]. pH of the milk samples was determined by the method of [7]. Casein determination in milk was carried using previously described AOAC method [15]. The determination of Total Solid was done following the method described by [10]. While, vitamin A was evaluated using the method of [16] with slight modification.

2.3.3 Determination of percentage yield and coagulation time

The yield of cheese was determined by a method described by [17], while a stop clock was used to determine the coagulation time [18]. Coagulation time was taken to be the time taken for the milk samples to coagulate after adding different coagulants.

2.3.4 Measurement of rancidity

Determination of peroxide value (PV) of the cheese samples was done following the method

outlined by [19]. Thiobarbituric Acid Reactive Substance (TBA-RS) determination was carried out using the method described by [20] with slight modification.

2.3.5 Microbiological analysis

Total bacteria and fungi counts of the cheese samples were determined according to the method as described by [21].

2.3.6 Sensory evaluation

Sensory evaluation was conducted using a trained panel consisting of twenty members who are familiar with cheese. The Panellists were instructed to evaluate the coded samples for appearance, aroma, taste, texture, and overall acceptability. Each sensory attribute was rated on a 9- point hedonic scale (9 = like extremely and 1 = dislike extremely) [7]. The cheese samples were served in 3-digit coded white plastics. The order of presentation of samples to the panellists was randomized. Sensory evaluation was carried out under controlled conditions of lighting and ventilation.

2.3.7 Statistical analyses

The data obtained were subjected to Analysis of Variance (ANOVA), while Duncan Multiple range test was used to separate means where significant differences existed, data analyses was achieved using the Statistical Package for Social Statistics (SPSS) software version 20.0. All analyses were performed in triplicate determinations.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Milk Samples

Results of proximate composition of the milk samples from coconut, soybean and cow are presented in Table 1. The moisture content of the milk samples ranged from 71.60% - 73.51%, with soy milk having the highest value. There was no significant (P > 0.05) variation between the moisture in coconut and cow milk. The moisture content for all milk samples were within the range (63.34% - 76.90%) which correlates with results reported by [22]. Determining the moisture content in milk is important because high moisture content implies high water activity which supports microbial growth and subsequent reduction the shelf life of the milk [23]. Low

moisture content on the other hand, implies low water activity which results in reduction of microbial growth and increased shelf life of milk [23]. The crude protein of cow milk was highest followed by soy and coconut milk respectively. Research finding of [24] showed crude protein value slightly lower than that obtained for soy milk variety in this study. Reduction in crude protein observed for soy milk could partly be attributed to the processing method adopted and/or type of soybean variety used in the study. The coconut milk had the highest fat content followed by cow and soybean varieties. Legume seeds are generally low in fats and oil [10], which probably explains the low fat content of soybean milk. High fat content in food is an indication of more total energies available [24]. Thus, coconut milk is high in total energy compared with other milk varieties as observed in this study. No noticeable value of crude fibre was detected for the cow milk whereas; the reverse was the case for coconut and soy milk with fibre content of 2.13% and 0.25% respectively. Fibre is well known to aid digestion and add bulk to the diet [10]. The ash content of the milk samples showed significant (P<0.05) difference with cow and coconut milk showing highest and lowest values respectively. Ash content in food is an indication of its total mineral element content [13]. There was significant difference (P<0.01) in the carbohydrate content of the milk samples with soybean milk having the highest value followed by cow milk. Aside lactose which occurs as a major carbohydrate in cow milk, there is also small amounts of glucose, gelatos and others. Carbohydrate contributes to the bulk of energy found in the milk. The calories are provided by the protein, fat and carbohydrate which can help to meet the energy requirement.

3.2 Proximate Composition of the Cheese Samples

Table 2 shows the result of proximate composition of the cheese samples made from coconut, soy and cow milk. Moisture content of the cheese produced from coconut, soy and cow milk varied between 42.64 to 57.10 %, 48.19 to 56.31% and 45.92 to 62.44 % respectively, using lime, lemon and rennet as coagulants. Moisture content of rennet coagulated cheese was significantly (P < 0.05) higher than lemon and lime coagulated cheese. The disparities observed in the moisture content of the formulated cheese varieties may be attributed to the coagulating strength of the selected coagulants used in the current study. The

moisture content of cheese produced from cow milk was significantly ($P < 0.05$) higher than those produced from soy milk and coconut milk. Higher moisture content could favour growth and proliferation of microorganisms; thus reducing the shelf-life of cheese [2]. There were significant ($P < 0.05$) variations in the protein profile of the studied cheese samples. Besides the cheese from coconut milk, that of soy and cow milk had higher protein content than those reported by [25]. The disparity seen in the protein content of cheese in this study could probably be due to the differences in the plant materials used, coagulant type and method of processing adopted. The relative high amount of protein observed especially in the coagulated soy, and cow milk formulated cheese could help address protein deficiencies which is prevalent in Nigeria. For all samples, fat content of lime coagulated cheese products was significantly ($P < 0.05$) higher than lemon and rennet coagulated cheese. This could probably be attributed to the decrease in fat recovery from lemon and rennet coagulants which could have led to the release of more fat content to the whey. Table 2 also revealed that cheese made from cow milk coagulated with lime, lemon and rennet contain higher amounts of fat than those made from soy and coconut milk respectively. The result for crude fibre showed that lime, lemon and rennet coagulated cheese samples from coconut milk were higher than those from soy milk. For all samples, fibre content of lime coagulated cheese was significantly ($P < 0.05$) higher than of lemon and rennet. Crude fibre was absent for cow milk based cheese. Similar result was also reported by [1]. The ash content in foodstuff is a measure of mineral elements in food [1]. Cheese samples made from cow milk using different coagulants were significantly ($P < 0.05$) higher in total ash content than those produced from soy, and coconut milk. Carbohydrate value ranged from 0.94 % to 34.30% among the samples using different coagulants, with the highest content recorded for cheese made from coconut milk followed by that from soy milk.

3.3 Physicochemical Properties

The physicochemical properties of milk samples from coconut, soybeans, and cow are presented in Table 3. Among all milk samples evaluated, cow milk had the highest specific gravity (1.00 g/ml), while coconut milk had the least specific gravity (0.97 g/ml). There was no difference between samples, S_oM_i and C_wM_i; while a significant ($p < 0.05$) difference was observed for

sample C_oM_i. The specific gravity of normal fresh milk ranged from 1.027 to 1.035 g/ml with a mean value of 1.032 g per ml [14]. This falls out of range with results obtained from the current study. The TTA of Sample C_wM_i containing cow milk was significantly ($P < 0.05$) higher than those of samples, S_oM_i and C_oM_i. This may be as a result of microbial proliferation during transportation from where the cow milk was purchased. The percentage of acid present in milk is a rough indicator of its age [14]. Normal fresh milk has an apparent acidity of 0.14 to 0.16% as lactic acid [26]. Table 3 also shows the inverse relationship that exists between TTA and pH. The higher the pH, the lower the TTA and vice versa [10]. Fresh cow milk typically has a pH between 6.5 and 6.7. As milk goes sour, it becomes more acidic and the pH gets lower. Casein is the most important protein in milk, while the proportion of whey proteins is relatively low [27]. The cow milk contained casein, but was absent in coconut, and soy milk. Casein is found only in animal and human milk, but not in milk of plant origin. The Total Solids (TS) content in coconut milk was significantly ($P < 0.05$) higher than those of soy, and cow milk respectively. The values reported in this study followed similar trend with those reported by [28] who revealed that considerable content of TS and fat was detected in coconut milk than in cow milk. Vitamin A was significant ($P < 0.05$) among the three samples. Vitamin A was higher in cow milk (15.23 mg/l) compared to coconut, (1.61 mg/l) and soy milk (9.96 mg/l) respectively as presented in Table 3. This clearly shows that milk gotten from cow is richer in vitamin A than soy, and coconut. Vitamin A promotes good vision, immune system integrity, growth, cellular differentiation and proliferation [13].

3.4 Coagulation Time and Percentage Yield

The coagulation time and cheese yield for coconut milk varied between 70 to 147 sec and 12.40 to 18.60%; soy milk varied between 19 to 60 sec and 20.20 to 25.60%, while cow milk varied between 52 to 60 sec and 22.50 to 28.70 %, respectively. It can be seen from Table 4 that the difference in coagulant type significantly affected coagulation time and cheese yield from coconut, soy and cow milk accordingly. This might be due to differences in pH of the coagulants used. Lemon which has the lowest pH (2.98) coagulates milk faster when compared with lime, and rennet having pH of 5.5 and 6.3 respectively. This is assumed to have also

Table 1. Proximate composition of milk samples produced from coconut, soybean and cow

Samples	Parameters (%)					
	Moisture content	Crude protein	Crude fat	Crude fibre	Total ash	Carbohydrate content
C_oM_i	$71.60^b \pm 0.44$	$3.65^c \pm 0.02$	$6.71^a \pm 0.01$	$2.13^a \pm 0.02$	$0.66^c \pm 0.03$	$15.25^c \pm 0.04$
S_oM_i	$73.51^a \pm 0.35$	$4.99^b \pm 0.01$	$2.30^c \pm 0.01$	$0.25^b \pm 0.04$	$0.86^b \pm 0.02$	$18.09^a \pm 0.02$
C_wM_i	$72.10^b \pm 0.02$	$5.80^a \pm 0.03$	$5.02^b \pm 0.02$	-	$0.95^a \pm 0.02$	$16.13^b \pm 0.01$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different (P < 0.05).

C_oM_i = Coconut milk; S_oM_i = Soy milk; C_wM_i = Cow milk

affected the cheese yield since it had been reported by [29] that a coagulant with longercoagulation period increases the moisture content of cheese which in turn leads to increased cheese yield. Rennet which took longer period of coagulation was observed to have the highest percentage of cheese yield. Research report by [30] revealed that a longer rennet coagulation time (firmer coagulum at cutting) resulted in an increase in cheese moisture, as well as an increase in cheese yield. Similarly, it can also be seen from the results that difference in milk source had significant effect on the coagulation time as well as cheese yield. This could be due to differences in milk composition such as the milk

Table 2. Proximate composition of the cheese produced from coconut, soy and cow milk

Samples	Parameters (%)					
	Moisture content	Crude protein	Crude fat	Crude fibre	Total ash	Carbohydrate content
A_{CL}	$42.64^i \pm 0.04$	$10.53^i \pm 0.03$	$9.59^d \pm 0.01$	$1.32^a \pm 0.02$	$1.62^f \pm 0.01$	$34.30^a \pm 0.10$
B_{CL}	$53.56^e \pm 0.01$	$11.59^h \pm 0.00$	$7.68^e \pm 0.01$	$1.27^b \pm 0.00$	$1.58^g \pm 0.01$	$24.32^b \pm 0.16$
C_{CR}	$57.10^c \pm 0.01$	$11.98^g \pm 0.02$	$6.12^g \pm 0.01$	$1.20^c \pm 0.01$	$1.56^g \pm 0.01$	$22.04^c \pm 0.14$
D_{SL}	$48.19^g \pm 0.01$	$20.39^f \pm 0.00$	$6.90^f \pm 0.01$	$0.92^d \pm 0.02$	$1.64^f \pm 0.01$	$21.96^c \pm 0.15$
E_{SL}	$49.60^f \pm 0.01$	$22.57^e \pm 0.02$	$5.78^h \pm 0.01$	$0.83^e \pm 0.04$	$1.72^d \pm 0.01$	$19.50^d \pm 0.11$
F_{SR}	$56.31^d \pm 0.01$	$22.68^d \pm 0.02$	$5.12^i \pm 0.02$	$0.87^e \pm 0.02$	$1.68^e \pm 0.01$	$13.34^f \pm 0.19$
G_{CL}	$45.92^h \pm 0.06$	$23.69^c \pm 0.01$	$11.97^a \pm 0.02$	-	$2.32^a \pm 0.02$	$16.10^e \pm 0.12$
H_{CL}	$61.28^b \pm 0.02$	$24.84^a \pm 0.02$	$10.53^b \pm 0.01$	-	$2.15^c \pm 0.01$	$1.20^g \pm 0.28$
I_{CR}	$62.44^a \pm 0.04$	$24.02^b \pm 0.01$	$10.34^c \pm 0.03$	-	$2.26^b \pm 0.04$	$0.94^h \pm 1.00$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different (P < 0.05). A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

Table 3. Physicochemical properties of milk samples produced from coconut, soybean and cow

Samples	Parameters (%)					
	S.G (g/ml)	TTA (%)	pH	Casein	% TS	Vitamin A (mg/l)
C_oM_i	$0.97^b \pm 0.00$	$0.07^c \pm 0.00$	$6.90^a \pm 0.01$	-	$16.35^a \pm 0.14$	$1.61^c \pm 0.00$
S_oM_i	$0.99^a \pm 0.01$	$0.19^b \pm 0.00$	$6.60^b \pm 0.01$	-	$7.72^c \pm 0.11$	$9.96^b \pm 0.00$
C_wM_i	$1.00^a \pm 0.03$	$0.78^a \pm 0.00$	$4.16^c \pm 0.05$	$6.96^a \pm 0.03$	$9.41^b \pm 0.09$	$15.23^a \pm 0.00$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different (P < 0.05). C_oM_i = Coconut milk; S_oM_i = Soy milk; C_wM_i = Cow milk; S.G= Specific Gravity; TTA= Total Titratable Acidity; TS= Total Solids

Table 4. Effect of coagulant type on the coagulation time and cheese yield of the milk samples

Samples	Parameter	
	Coagulation time (sec)	Cheese yield (%)
A_{CL}	$70^c \pm 2.00$	$12.40^g \pm 0.10$
B_{CL}	$147^a \pm 2.00$	$15.30^g \pm 0.10$
C_{CR}	$120^b \pm 1.00$	$18.60^f \pm 0.10$
D_{SL}	$27^f \pm 1.00$	$22.30^d \pm 0.10$
E_{SL}	$19^g \pm 1.00$	$20.20^e \pm 0.10$
F_{SR}	$60^d \pm 1.00$	$25.60^b \pm 0.20$
G_{CL}	$53^e \pm 1.00$	$24.20^c \pm 0.10$
H_{CL}	$60^d \pm 1.00$	$22.50^d \pm 0.10$
I_{CR}	$52^e \pm 1.00$	$28.70^a \pm 0.10$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different (P < 0.05). A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

Table 5. Peroxide Value (mEq/kg) of cheese at room temperature

Sample/Day	0	1	2	3	4	5
A_{CL}	$2.31^i\pm0.04$	$4.14^i\pm0.03$	$32.26^i\pm0.01$	$93.39^b\pm0.13$	$42.62^g\pm0.03$	$39.21^g\pm0.04$
B_{CL}	$3.87^g\pm0.01$	$11.13^g\pm0.00$	$43.45^h\pm0.01$	$46.55^i\pm0.01$	$55.31^d\pm0.03$	$52.82^d\pm0.02$
C_{CR}	$4.10^f\pm0.01$	$12.23^f\pm0.00$	$54.56^e\pm0.00$	$62.21^f\pm0.01$	$70.22^c\pm0.02$	$68.65^c\pm0.00$
D_{SL}	$12.54^b\pm0.01$	$37.69^b\pm0.00$	$84.83^b\pm0.02$	$47.25^h\pm0.02$	$36.82^i\pm0.02$	$33.23^i\pm0.02$
E_{SL}	$8.90^d\pm0.02$	$26.69^c\pm0.01$	$71.20^c\pm0.01$	$58.05^g\pm0.01$	$38.85^h\pm0.01$	$35.15^h\pm0.03$
F_{SR}	$3.28^h\pm0.02$	$9.61^h\pm0.02$	$48.02^f\pm0.02$	$89.67^c\pm0.02$	$87.81^b\pm0.01$	$86.21^b\pm0.01$
G_{CL}	$9.12^c\pm0.05$	$24.33^d\pm0.04$	$56.81^d\pm0.01$	$197.74^a\pm0.03$	$118.52^a\pm0.02$	$90.10^a\pm0.01$
H_{CL}	$19.67^a\pm0.03$	$60.00^a\pm0.02$	$109.98^a\pm0.01$	$73.54^e\pm0.01$	$45.72^f\pm0.02$	$42.78^f\pm0.01$
I_{CR}	$5.31^e\pm0.03$	$15.66^e\pm0.02$	$44.25^g\pm0.03$	$79.68^d\pm0.01$	$54.13^e\pm0.03$	$52.26^e\pm0.03$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different ($P < 0.05$).

A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

Table 6. Malonaldehyde measurement of oxidized cheese with Thiobarbituric (TBA-RS) acid (mg MDA/kg)

Sample/Day	1	2	3	4	5	6	7
A_{CL}	$0.36^a\pm0.00$	$3.47^b\pm0.00$	$3.59^b\pm0.00$	$3.63^b\pm0.03$	$3.66^b\pm0.00$	$3.65^b\pm0.00$	$3.27^d\pm0.00$
B_{CL}	$0.23^d\pm0.00$	$1.82^f\pm0.00$	$2.57^g\pm0.00$	$3.35^c\pm0.00$	$3.42^c\pm0.00$	$3.37^c\pm0.06$	$3.41^c\pm0.00$
C_{CR}	$0.16^e\pm0.00$	$0.94^h\pm0.02$	$1.66^i\pm0.00$	$2.24^h\pm0.00$	$2.51^h\pm0.00$	$2.57^g\pm0.00$	$2.56^g\pm0.02$
D_{SL}	$0.31^c\pm0.00$	$2.38^e\pm0.08$	$3.34^c\pm0.00$	$3.34^d\pm0.01$	$3.36^d\pm0.05$	$2.85^e\pm0.00$	$3.59^b\pm0.00$
E_{SL}	$0.23^d\pm0.00$	$2.64^d\pm0.00$	$2.73^e\pm0.00$	$2.80^f\pm0.00$	$2.78^f\pm0.00$	$2.70^f\pm0.02$	$2.70^f\pm0.00$
F_{SR}	$0.23^d\pm0.00$	$1.74^g\pm0.01$	$2.60^f\pm0.00$	$2.66^g\pm0.00$	$2.53^g\pm0.00$	$2.54^h\pm0.00$	$2.45^h\pm0.00$
G_{CL}	$0.10^g\pm0.00$	$1.75^g\pm0.00$	$2.07^h\pm0.00$	$2.12^i\pm0.00$	$2.20^i\pm0.00$	$1.92^i\pm0.00$	$1.85^i\pm0.00$
H_{CL}	$0.12^f\pm0.00$	$4.52^a\pm0.00$	$4.62^a\pm0.57$	$5.38^a\pm0.10$	$4.65^a\pm0.00$	$4.49^a\pm0.00$	$4.37^a\pm0.01$
I_{CR}	$0.34^b\pm0.00$	$2.66^c\pm0.00$	$2.88^d\pm0.00$	$2.81^e\pm0.00$	$2.80^e\pm0.00$	$2.86^d\pm0.00$	$2.75^e\pm0.00$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different ($P < 0.05$).

A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

pH, protein and fat content which are the main factors that affect coagulation time and cheese yield. Cheese yield is vital in an economic sense for cheese makers, since small differences in yield translate into big differences in profits [30].

3.5 Rancidity Determination

3.5.1 Peroxide values (mEq/kg) of cheese at room temperature

Peroxide Values in the 30-40 mEq/Kg range are generally associated with a rancid taste [31]. In this study, the different formulated cheese varieties were exposed to room temperature for five days. From Table 5, besides samples D_{SL} and H_{CL}, all other freshly prepared cheese at the 0th day fell within the standard value of 10 mEq/kg; specified by Standard Organization of Nigeria and Nigerian Industrial Standard [32]. However, with increase in storage time, virtually all the samples went rancid. Peroxide Value (PV) is an indicator of the extent of oxidation of lipids, fats, and oils [33], as well as rancidity in foods, but does not provide information on secondary oxidation products [34]. High Peroxide Value points to how likely a food product are prone to rancidity. Increasing Peroxide Values occurs because of the oxidation process of unsaturated fatty acids in oil with the aid of oxygen [31]. The use of an antioxidant extract can be used to reduce the rate of peroxide formation during the storage of the formulated cheese products.

3.5.2 Malondialdehyde measurement of oxidized cheese with thiobarbituric (TBA-RS) acid

The cheese produced was stored for a period of 7 days to determine the extent of rancidity. For day 1, all the cheese samples' Thiobabituric Acid Reactive Substance ranged from 0.10 to 0.36 mg MDA/kg. This was within the permissible level of 2.0 mg MDA/kg [35]. From day 2, rancidity began to set in gradually and from day 3 to 7, almost all cheese became rancid. Thiobabituric Acid Reactive Substances (TBA-RS) are formed as a by-product of lipid peroxidation. TBA-RS is defined as the increase of absorbance measured at 530 nm due to reaction of the equivalent of 1 mg of test sample per 1 mL volume with 2-Thiobarbituric acid forming condensation products.

3.6 Microbiological Analysis

The microbial (fungal and bacterial) load of the different milk cheese is shown in Table 7. No fungal growth was found in samples A_{CL}, B_{CL} and C_{CR}, while other samples showed fungal growth. The bacterial load ranged from 2.5×10^2 to 3.1×10^3 CFU/g. The study thus, reveals that all samples were microbiologically safe for human consumption, since the microbial loads did not exceed the acceptable limits of $>10^5$ recommended by the International Commission of Microbiology Specifications of Foods [10]. This is an indication that the formulated cheese samples were well processed under good hygienic conditions.

3.7 Sensory Evaluation

Table 8 shows results of the sensory attributes of cheese made from coconut, soy, and cow milk using lime, lemon and rennet as coagulants. Generally, the sensory scores ranged from 5.00 to 8.65 on a 9-Point hedonic scale. This reveals that all cheese samples were organoleptically acceptable, because their scores

Table 7. Microbiological analysis of cheese produced from coconut, soy and cow milk

Samples	Fungal count (CFU/g)	Bacterial count (CFU/g)
A_{CL}	-	1.7×10^3
B_{CL}	-	2.5×10^2
C_{CR}	-	3.1×10^2
D_{SL}	6.1×10^2	1.6×10^3
E_{SL}	7.1×10^2	2.4×10^3
F_{SR}	3.1×10^2	3.1×10^3
G_{CL}	7.1×10^2	7.5×10^2
H_{CL}	7.2×10^2	8.5×10^2
I_{CR}	3.1×10^2	6.1×10^2

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different ($P < 0.05$). A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

Table 8. Sensory evaluation of cheese produced from coconut, soy and cow milk

Samples	Appearance	Aroma	Taste	Texture	Overall acceptability
A_{CL}	$5.80^{cd} \pm 1.00$	$8.85^{a} \pm 0.81$	$5.60^{cd} \pm 1.04$	$6.20^{bc} \pm 1.05$	$5.75^{bc} \pm 1.20$
B_{CL}	$5.90^{cd} \pm 0.85$	$8.10^{ab} \pm 1.02$	$7.10^{a} \pm 0.78$	$5.25^{cd} \pm 1.09$	$6.00^{bc} \pm 0.85$
C_{CR}	$6.00^{cd} \pm 1.06$	$8.65^{ab} \pm 0.98$	$6.95^{ab} \pm 0.94$	$5.00^{cd} \pm 1.02$	$5.75^{bc} \pm 1.06$
D_{SL}	$8.10^{ab} \pm 1.11$	$7.25^{bc} \pm 0.91$	$5.15^{cd} \pm 0.60$	$8.50^{a} \pm 0.60$	$8.50^{a} \pm 0.51$
E_{SL}	$8.55^{a} \pm 0.82$	$7.15^{bc} \pm 0.58$	$5.75^{bc} \pm 0.67$	$7.25^{ab} \pm 0.96$	$8.10^{a} \pm 0.78$
F_{SR}	$8.40^{ab} \pm 0.75$	$7.20^{bc} \pm 0.82$	$6.55^{ab} \pm 0.88$	$6.40^{bc} \pm 0.88$	$6.45^{b} \pm 0.68$
G_{CL}	$6.25^{cd} \pm 0.55$	$6.30^{cd} \pm 0.73$	$6.25^{bc} \pm 0.85$	$6.35^{bc} \pm 0.74$	$6.00^{bc} \pm 0.72$
H_{CL}	$6.60^{bc} \pm 0.50$	$6.40^{cd} \pm 0.82$	$7.05^{a} \pm 0.75$	$6.05^{bc} \pm 1.05$	$6.25^{bc} \pm 0.71$
I_{CR}	$6.65^{bc} \pm 0.87$	$6.35^{cd} \pm 0.93$	$7.40^{a} \pm 1.23$	$5.20^{cd} \pm 0.76$	$6.35^{bc} \pm 1.03$

Values are means ± SD of triplicate determinations. Means with different superscripts within the same column are significantly different (P < 0.05)

A_{CL} = Coconut milk + Lime; B_{CL} = Coconut milk + Lemon; C_{CR} = Coconut milk + Rennet; D_{SL} = Soy milk + Lime; E_{SL} = Soy milk + Lemon; F_{SR} = Soy milk + Rennet; G_{CL} = Cow milk + Lime; H_{CL} = Cow milk + Lemon; I_{CR} = Cow milk + Rennet

were above average. There was more preference for sample E_{SL} for appearance; sample A_{CL} for aroma; samples B_{CL}, H_{CL} and I_{CR} for taste; sample D_{SL} for texture; samples D_{SL} and E_{SL} for overall acceptability by the panellists.

4. CONCLUSION

The study reveals the possibility of producing cheese from plant sources: soy, and coconut, as excellent alternatives to cow milk for persons with lactose intolerance. It also established that lime and lemon are excellent substitutes for rennet for the production of cheese with high nutritional profile, and yield. All Cheese formulations were microbiologically safe, and scored above average in its organoleptic properties. Cheese made from soybeans and coconut should therefore be recommended to vegetarians as an alternative to meat, because of its rich protein value.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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