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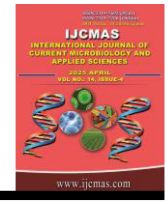

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Comparative Evaluation of Proximate Composition, Selected Minerals and Organoleptic Properties of Cheese Produced from Bunaji Cow Milk Using Different Coagulants

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ABSTRACT

Proximate composition, selected minerals and organoleptic properties of cheese produced from Bunaji cow milk using different coagulants was investigated under standard laboratory procedures. Ten (10) liters of fresh milk was collected and divided into four equal portions to represent four treatments (T1, T2, T3 and T4) to which coagulants extracts from *Callotropis procera* (T1)**,** *Carica papaya* (T2)*, Zyngiber officinale* (T3) and *Curcuma longa* (T4) were added to produce cheese. The results differed significantly (P<0.05) among treatments. Proximate values (%) of coagulants recorded highest Moisture in T3 (72.24), Crude protein (CP), 10.85 (T1), Ether extract, 8.25 (T2). Ash and crude fibre ranged from 4.00 (T3) to 7.21 (T1) and 6.50 (T3) to 8.20 (T1). Proximate values (%) of Cheese samples had highest CP value in T3 (21.00), fat, 3.65 (T1) and 2.60 (T1) for ash, respectively. The mineral contents (mg/100g) of coagulants placed Sodium (Na) at the highest record value of 55.50 (T1). Phosphorus (P) recorded 95.00 at T4, Potassium (K) was high in T3 (95.80), Calcium (Ca), 95.55 (T4), Iron (Fe), 32.75 (T1), Copper (Cu), 2.00 (T1) and Zinc (Zn), 3.50 (T4), respectively. Cheese samples recorded highest mineral values (mg/100g) of 550.05, 425.00, 175.07 and 33.33 for Calcium, Phosphorus, Potassium and Magnesium at T3 (*Zyngiber officinale* cheese sample), Sodium (Na) values ranged from 520.05 (T1) to 550.00 (T2). Copper (Cu) and Zinc (Zn) varied significantly (P<0.05) across treatments. Organoleptic properties showed positive overall acceptability of cheese samples. The study underscored the suitability of the selected coagulants for cheese production.

Introduction

Cheese production is one of the most important means of milk valorization, providing a nutrient-dense food that contributes significantly to dietary protein, fat, minerals, and vitamins (Abbaya *et al.,* 2020). In Nigeria, the White Fulani (Bunaji) cow is the predominant indigenous dairy breed, valued for its adaptability and milk production potential. However, despite its availability, limited attention has been given to improving local cheese processing using alternative coagulants that are affordable, safe, and nutritionally beneficial. The dependence on imported rennet for coagulation poses economic and sustainability challenges, thereby creating the need for exploring locally available plant-based coagulants as substitutes. Plant-derived coagulants such as *Calotropis procera* (sodom apple), *Carica papaya* (pawpaw), *Zingiber officinale* (ginger), and *Curcuma longa* (turmeric) are rich in proteolytic enzymes, minerals, and phytochemicals that can influence both the yield and nutritional composition of cheese. These coagulants not only provide a cost-effective alternative to animal rennet but also offer additional functional and health-promoting properties. For instance, ginger contains proteolytic enzyme that enhances milk protein coagulation, while *Calotropis procera* has traditionally been used in West Africa for cheese making. Thus, investigating their effects on the proximate composition of cheese produced from Bunaji cow milk is justified, as it can promote indigenous innovation, reduce production costs, and improve food security.

The White Fulani or Banaji cattle were reported as the leading triple purpose (meat, milk and draught) breed in West Africa. They also play an important role in the religion and social lives of the people. They serve as a reserve of family wealth and as a mark of respectability and status in the community (Ojedapo *et al.,* 2014). Cattle are well known to be the major source of milk worldwide, however, the milk production by local cattle breeds in Nigeria have been reported to be low due to the poor quality and insufficient feeds and feedstuffs especially during the dry season (Belewu, 2006).

In Nigeria and other parts of West Africa, milk collected from the cow is first used to feed the calves. The remaining milk is then consumed by the farmer's household and any surplus is made into butter or into an unripened soft cheese called wara. This unripened soft cheese is usually made by the addition of the extract from a plant, *Calotropis procera* to the whole milk from cattle (Belewu, 2006; Adetunji *et al.,* 2008; Akinloye and Adewumi, 2014). Cheese is a dairy product indispensable to human nutrition due to its high-value nutrients needed for the human body: milk casein (the main component of the coagulum), lipids, lactose and the products that are formed after its fermentation (lactic acid), as well as a significant amount of mineral salts (Alexa *et al.,* 2018).

Cheese making in simple sense is the separation of curd from whey and kneading into a mouldable consistency. It is a nutritious milk product made from the milk of cow and goat. It contains all the milk nutrients and even something more from the microbial fermentation. It is convenient and versatile, with a wide range of flavors and textures. In 2020, global cheese production amounted to about 21.69 million metric tons (Altafini *et al.,* 2021). Worldwide the top cheese producer was the European Union with a production volume of around 10.4million metric tons of cheese per year (Kossongo *et al.,* 2020).

Coagulant has one of the most significant roles in cheese manufacturing, and the traditional and most commonly used milk coagulating enzyme is rennet, which comes from calf (Roseiro *et al.,* 2003). In addition to milk quality, the cheese qualities are determined by milk coagulation, which is one of the most critical processes in the cheese making process. Coagulating agents that are used in the clotting process makes the differences in protein matrix degradation (by the hydrolysis of caseins and the production of hydrophobic peptides) that influences the cheese yield, texture profile (elasticity, fragility, adhesiveness, hardness, gumminess and chewiness) and flavour development (especially a bitter taste).

Traditionally, plant-based coagulants such as *Calotropis procera* (Sodom apple), Moringa oleifera leaf extract, and lime juice are used in local cheese-making as natural alternatives to commercial rennet. These coagulants are readily available, cost-effective, and culturally acceptable. Studies have shown that these plant extracts possess proteolytic enzymes and organic acids that can coagulate milk effectively while also contributing to the nutritional and functional properties of the cheese. However, the commonly used plant-based coagulants" *Calotropis procera"* has been identified not suitable for production of hard cheese (O'Connor and Tripathi, 1992). As consumer choices and demand increases for natural, nutrient-rich dairy products, there is a need to evaluate some identified plants with potentials for nutritional and coagulating properties, such as Papaya *(Carica papaya)*, Ginger *(Zyngiber officinale)* and Turmeric *(Curcuma tonga)*.

Papaya leaves have several vitamins and minerals in significant amounts, it is low in calories, and has an enzyme that is useful in tenderizing meat and for treatment of indigestion (Herbst S, 2001, Prior M, 2007) and curing thrombocytopenia (Imaga *et al.,* 2010). The leaves have been researched for its medicinal uses for its anti- inflammatory, antitumor, anti -diabetic effects among others. Recently the haemostatic property and beneficial effects of Carica papaya leaves in curing the dengue infected patients has been reported (Ahmad *et al.,* 2011). The leaves also contain active components such as papain chymopapin cystain, ascorbic acid, flavournoids, cynogenic glucosides that increases the total antioxidant power in blood and reduce lipid preoxidation level (Seigler *et al.,* 2002).

As reported by (ElMoussaoui, *et al.,* 2001), papaya leaves contains alkaloids with important pharmaceutical and industrial applications. The extract has anti-cancer, anti-oxidative, anti-inflammatory and anti-bacterial properties (Ranasinghe *et al.,* 2012), and in addition to this, it has nephro-protective and hepato-protective activity against toxins, hypoglycaemic and hypolipedemic effects. It also has anti-sickling properties in sickle cell disease. (Ranasinghe *et al.,* 2012). The nutrients content of papaya leaves makes it suitable for use as coagulant in cheese production

Ginger contains several phytochemical compounds which have biological activities such as antioxidation, antimicrobial and other pharmacological effects (Zhao *et al.,* 2011). The potential pharmacological effects of ginger in monogastric animal production have been documented (Tekeli *et al.,* 2011). Akbarian *et al.,* 2011 reported the potential feeding value of ginger on growth performance and carcass quality of broiler chickens. The nutritional importance of ginger plant is increasingly acknowledged worldwide (Nwinuka *et al.,* 2005); they have established to provide amino acids, oils, vitamins and mineral elements which are lacking inorganic feed additives (Al-Achi, 2007). Recently, numerous research efforts have been directed at the performance indices and optimal inclusion rate of ginger rhizome in monogastric feeding systems (Tekeli *et al.,* 2011). Although ginger may have performed well as a feed additive source, not much has been reported on its utilization as coagulant in cheese production. Tumeric is a medicinal plant that botanically belongs to Zingiberacea family (Chattopadhyan *et al.,* 2004). Turmeric is widely used as a spice and colouring agent and is known for its medicinal properties (Luthra *et al.,* 2001). Curcumin, a potent antioxidant is believed to be the most bioactive and soothing portion of the herb turmeric and posses the antioxidant, antimicrobial, anti - inflammatory, anti - platelet, cholesterol lowering, antibacterial and antifungal effects (Peter, 2000). The curcumin contain vitamins or vitamin precursor which produces vitamin C, beta - carotene as well as polyphenol coupled with fatty acid and essential oil. Turmeric is a good source of spice compared with other spices. The leaves are known as great source of vitamin and minerals (Chattopadhyan *et al.,* 2004). Tumeric has been used traditionally as household remedy in curing various diseases such as anorexia, cough, rheumatism and intestine disorder.

This study, therefore, aimed at investigating Papaya *(Carica papaya)*, Ginger *(Zyngiber officinale)* and Turmeric *(Curcuma tonga)* alongside *Calotropis procera* as they may affect the proximate composition, selected minerals and organoleptic properties of cheese produced from Bunaji cow milk.

Materials and Methods

Experimental Site

The experiment was carried out at Fasola Village in Iseyin Local Government Area of Oyo State, The laboratories of Animal Nutrition and Biotechnology of Ladoke Akintola University of Technology, Ogbomoso, Oyo State on Latitude 8˚8’32.7940”N of the equator and Longitude 4˚14’42.6696”E of the Greenwich meridian (Google Earth Map 2025) and Microbiology Department, University of Ilorin, Kwara State, Nigeria, Latitude 8.4799°N and Longitude 4.5418°E of the Greenwich meridian (Google Earth Map 2025). Both institutions are located in the derived savannah zone of Nigeria.

Collection of Milk

Fresh milk was collected from lactating Bunaji cows from a Fulani herd settlement and transported in an air tight milk jar or Flask to the Laboratory. Four (4) samples of milk was collected randomly to represent Four treatments (T1, T2, T3 and T4), to which each of the selected coagulants were applied in the process of cheese making.

Laboratory Procedures of Cheese Making and selected coagulants

The selected coagulants Bombom *(Callortopis procera)* Papaya *(Carica papaya)* Ginger (*Zyngiber officinale*) and Turmeric *(Curcuma tonga*) used were sourced from LAUTECH Teaching and Research Farm, Ogbomoso, Oyo State. In the laboratory, extract of each of the coagulants were prepared. 5-20ml of 1N HCl was added to each of the milk sample and later, 5ml of each of the coagulants; to each of the samples. At this point, coagulation process had commenced. This was followed by gentle heating to 32ºC for 30 minutes to complete coagulation. During coagulation process, the beakers were not disturbed to prevent the curds from breaking into pieces too small to filter efficiently with cheese cloth. At the completion of coagulation; the temperature was gradually increased to 38ºC. This slightly elevated temperature and facilitated the separation of the curd from the whey. After the curd is separated from the whey, breaking up of the curds was done with a stirring rod, the whey from each treatment was drained through layers of cheese cloth for better results. The curd obtained were weighed in its wet state to approximate the yield. The curd was wrapped in cheese cloth and pressed for 12 hours to remove the additional whey soaked in the curd. The curd hardened and formed a cheese block in the shape of the press as the whey was squeezed out. The cheese block was dried for 6 hours, after which it was presented for sensory evaluation.

Laboratory Analysis

Proximate analysis of selected coagulants (*Callotropis procera, Carica papaya, Zyngiber officinale* and *Curcuma longa*), raw milk and cheese samples were analyzed as described by AOAC (2005). Total Solids (TS) was determined by spreading out 20g of asbestos in the bottom of a porcelain dish. Heat was applied and later allowed to cool in a desiccator and weighed accordingly. 20 mls of milk was run slowly into the dish and reweighed. The porcelain dish was then heated over a water bath at 65ºC for 30 minutes and dried in a thermostatically steam-controlled electric oven to constant weight for the total solids. Cheese and milk samples were analyzed for fat by the standard Gerber Method (AOAC, 2005). Protein contents were determined by the conventional Micro Kjeldahl method, solids not-fat was determined by difference (% total solids % fat). The percent lactose in the raw milk sample was calculated by subtracting summation of protein, fat and ash from total solids *"Lactose = Total Solids – (Protein + Fat + Ash)"*. Mineral Analysis were carried out by Wet digestion of samples procedure using Atomic Absorption Spectro-photometer (AAS).

Organoleptic Evaluation

Organoleptic evaluation of the cheese samples was done by 5 panelists who had been trained on sensory skills of judgement to determine flavour (Olfactory and Tongue), taste and texture (Tongue) and colour (Visual). The four cheese samples were coded randomly and panelists were allowed independent judgement to ensure standardized results.

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using the procedure of (SAS, 2003) package to determine the suitability of selected coagulants in cheese production. Significant means were separated using Duncan multiple range test at 5% probability level of the same software.

Experimental Design

The experiment followed a Completely Randomized Design (CRD)

Results and Discussion

Proximate composition of raw milk from White Fulani cows

Table 1 showed the results for proximate composition of raw milk from Bunaji cows. The parameters evaluated include total solids, protein, fat, solids-not-fat, ash, lactose, and casein. The values (%) recorded include Total Solids (13.10), Protein (3.25), Fat (4.10), Solids-non-fat (8.05), Ash (1.26), Casein (2.50), while Lactose was calculated as Total solids – (Protein + Fat + Ash); to give 4.49% with Mean values ± standard deviation to each constituent as shown in the table. The values recorded aligned with the range of values recorded by (Ojedapo *et al.,* 2014). The variation could be traced to the nutritional qualities of the feed offered the animals as well as environmental factor(s) of locations of the cattle settlements.

Table 2 presents the results of proximate composition of selected fresh coagulants which include *Callotropis* *procera, Carica papaya, Zyngiber officinale and Curcuma longa.* The results showed no significant different (P>0.05) between *Callotropis procera* and *Carica papaya*. The Moisture content (%) ranged from 65.00% in *Carica papaya* to 72.24% in *Zyngiber officinale*. For crude protein (%), the lowest value recorded was 8.50 in *C. longa*, while the highest value was 10.85 in *C. procera. Carica papaya* had the highest value of 8.25% in Ether extract while *Callotropis procera* recorded the lowest value of 4.58%. The ash values ranged from 4.00% (*Zyngiber officinale)* to 7.21% (*Callotropis procera)*. The Nitrogen Free Extract values was significant (P<0.05) across the treatments (Coagulants).

The mineral composition (mg/100g) of selected coagulants (Table 3) differed significantly (P<0.05) among the treatments. *Curcuma longa* had the highest composition (mg/100g) of the major minerals investigated, with record values of 35.38, 90.00, 95.00, 85.00 and 95.55 for Sodium (Na), Magnesium (Mg), Phosphorous (P) and Calcium (Ca) with trace mineral (mg/100g) values of 15.75, 24.88, 1.25 and 3.50 for Manganese (Mn), Iron (Fe), Copper (Cu) and Zinc (Zn), respectively. All major and minor minerals investigated were significantly different (P<0.05) across the treatments (Coagulants), signifying variation in the composition of parameters of interest in the study.

The proximate composition and organoleptic properties of cheese from Bunaji cows were presented in Tables 4 and 5. Moisture content (%) ranged from 68.50 in *Callotropis procera* cheese sample to 73.00 in *Zyngiber officinale* cheese sample. Crude protein (%) recorded 7.00% in *Callotropis procera* cheese sample which was the lowest, compared with other coagulants. Fat and ash contents (%) recorded higher values in cheese sample coagulated by *C. procera* (3.65 and 2.60). Cheese sample produced by *Zyngiber officinale* had the lowest value of 1.50% and 1.90% Fat and ash contents. However, samples coagulated with *C. papaya* had 2.25% for Fat value while C. longa recorded 2.35%. In all, cheese sample coagulated with *Zingiber officinale* had overall desirable proximate value for consumption due to its crude protein, fat and ash contents, followed by *C. longa* treated cheese, ahead of *C. papaya* cheese samples. The coagulants improved the cheese quality compared to the *C. procera* commonly used in most communities where cheese is being produced.

The organoleptic properties of the cheese produced with the coagulants used in this study are desirable and promises acceptability to consumers. However, the choice of coagulant solely depend on the choice of cheese producer, following targeted quality as may be requested by consumers as well as shelf life.

In all, the cheese produced in this study met the overall acceptability of the cheese of good and standard judgement for human consumption.

Table 6 presents the effects of different coagulants on the selected mineral composition of cheese from Bunaji cow milk. The results are significantly affected (P<0.05) across the treatments. *Zyngiber offinale* cheese sample recorded highest values predominantly for major minerals. Calcium (Ca) values ranged from 420.20mg/100g (*Carica papaya* cheese sample) to 550.05mg/100g (*Zyngiber officinale* cheese sample). Same trend was observed for Magnesium (Mg) with recorded values of 33.33mg/100g (Ginger cheese sample), 32.00mg/100g for *C. longa* Cheese sample, followed by Cheese sample processed with *Callotropis procera* (28.00mg/100g), and the least value of 26.55mg/100g for cheese sample on *Carica papaya* coagulant. Copper (Cu) and Zinc (Zn) were significantly affected (P<0.05) across the treatments among trace minerals investigated with recorded values of 0.18 and 3.45mg/100g *(Zyngiber officinale),* and 0.9mg/100g (Carica papaya cheese sample) and 3.36mg/100g, for Cu and Zn, respectively.

The proximate composition of the selected coagulants indicated substantial variation in their nutritional attributes. *Zyngiber officinale* had 72.24% ahead of *Curcuma longa*, with record value of 70.00% moisture content, There was no significant difference (P>0.05) in the Moisture content of *Calotropis procera* and *Carica papaya* as they both recorded 65.50% and 65.00% moisture content, respectively. *Callotropis procera* recorded the highest crude protein (10.85%) and ash (7.21%). The relatively high protein in *Callotropis procera* suggests higher enzymatic activity, while the high carbohydrate levels in *Curcuma longa* (60.50%) may also play a role in curd firmness. The observed variations support earlier findings by Adetunji *et al.,* (2008), who noted that coagulants like *Callotropis procera* and *Carica papaya* yield cheeses with significantly different proximate compositions.

Table.1 Proximate composition of raw milk from White Fulani cows

Composition	(%)
Total Solids	13.10 ± 0.50
Protein	3.25 ± 0.50
Fat	4.10 ± 0.52
Solids-non-fat	8.05 ± 0.65
Ash	1.26 ± 0.05
Lactose	4.49 ± 0.75
Casein	2.64 ± 0.25

Lactose was calculated as total solids – (protein + fat + ash)

Table.2 Proximate composition of selected coagulants

Parameters (%)	*Callotropis procera* T1	*Carica papaya* T2	*Zyngiber officinale* T3	*Curcuma longa* T4	SEM
Moisture	65.50^{c}	65.00^{c}	72.24^{a}	70.00^{b}	3.50
Crude Protein	10.85^{a}	9.00^{b}	8.55^{b}	8.50^{b}	1.15
Ether extract	4.58^{d}	8.25^{a}	6.05^{b}	5.70^{c}	1.00
Ash	7.21^{a}	6.00^{b}	4.00^{d}	5.50^{c}	1.00
Crude Fibre	8.20^{a}	7.90^{b}	6.50^{c}	7.00^{c}	1.00
NFE	3.66^{b}	3.85^{a}	2.66^{d}	3.30^{c}	-

^{abcd} *means within the same row with different superscripts are significantly different (P<0.05).*

Table.3 Mineral Composition of Selected Coagulants (mg/100g)

Minerals (mg/100g)	*Callotropis procera* T1	*Carica Papaya* T2	*Zyngiber officinale* T3	*Curcuma longa* T4
Major Minerals				
Sodium (Na)	55.50^{a}	34.82^{b}	15.05^{c}	35.38^{b}
Magnesium(Mg)	50.00^{c}	65.45^{b}	50.20^{c}	90.00^{a}
Phosphorus (P)	80.75^{c}	85.50^{b}	30.00^{d}	95.00^{a}
Potassium (K)	35.00^{d}	75.50^{c}	95.80^{a}	85.00^{b}
Calcium (Ca)	50.00^{c}	85.50^{b}	40.05^{d}	95.55^{a}
Trace Minerals				
Manganese (Mn)	5.05^{b}	0.20^{c}	0.55^{c}	15.75^{a}
Iron (Fe)	32.75^{a}	3.00^{c}	0.60^{d}	24.88^{b}
Copper (Cu)	2.00^{a}	0.35^{d}	0.50^{c}	1.25^{b}
Zinc (Zn)	2.25^{b}	1.05^{c}	0.34^{d}	3.50^{a}

^{abcd} *means within the same row with different superscripts are significantly different (P<0.05).*

Table.4 Proximate Composition of cheese from Bunaji cow milk using different coagulants

Samples / Parameters (%)	Moisture	Crude Protein	Fat	Ash	Crude Fiber
***C. procera* Cheese Sample**	68.50^{ab}	7.00^{b}	3.65^{a}	2.60^{a}	-
***C. papaya* Cheese Sample**	70.00^{b}	19.85^{a}	2.25^{b}	2.00^{c}	-
***Z. officinale* Cheese Sample**	73.00^{a}	21.00^{b}	1.50^{c}	1.90^{c}	-
***C. longa* Cheese Sample**	71.20^{b}	20.65^{a}	2.00^{b}	2.35^{b}	-

^{abcd} *means within the same row with different superscripts are significantly different (P<0.05).*

Table.5 Organoleptic Properties of cheese from Bunaji Cow milk using Different Coagulants

Parameters / Samples	*Callotropis procera* Sample T1	*Carica papaya* Sample T2	*Zyngiber officinale* Sample T3	*Curcuma longa* Sample T4
Colour	White	Slightly white	Off white	Cream
Flavour	Off flavour	Off flavour	Very strong	Slightly strong
Taste	Sweet	Slightly sweet	Very Sweet	Sweet
Texture	Soft	Soft	Slightly hard	Firm
Overall Acceptability	Good	Good	Excellent	Very good

Table.6 Selected Mineral composition of cheese from Bunaji cow milk using different coagulants

Minerals (mg/100g)	*Callotropis procera* Sample T1	*Carica Papaya* Sample T2	*Zyngiber officinale* Sample T3	*Curcuma longa* Sample T4	SEM
Major Minerals					
Calcium (Ca)	426.50 ± 20.00[c]	420. 20 ± 10.05[d]	550.05 ± 14.10[a]	510.00 ± 11.10[b]	10.05
Magnesium(Mg)	28.00 ± 1.20[b]	26.55 ± 1.50[b]	33.33 ± 2.50[a]	32.00 ± 3.50[a]	2.75
Sodium (Na)	520.05 ±15.60[d]	550.00 ± 12.50[a]	535.00 ± 24.50[c]	538.75 ± 24.00[b]	8.08
Phosphorus (P)	335.80 ± 17.80[d]	340.50 ± 12.15[c]	425.00 ± 15.50[a]	418.22 ± 15.00[b]	12.15
Potasium (K)	140.40 ±5.52[d]	155.75 ± 2.28[c]	175.07 ± 7.75[a]	168.25 ± 5.05[b]	5.21
Trace Minerals					
Copper (Cu)	0.07 ± 0.01[d]	0.09 ± 0.05[c]	0.18 ± 0.05[a]	0.15 ± 0.02[b]	0.01
Iron (Fe)	0.77 ± 0.05[c]	0.85 ± 0.02[b]	0.90 ± 0.05[a]	0.90 ± 0.01[a]	0.01
Manganese (Mn)	0.06 ± 0.01[c]	0.25 ± 0.01[b]	0.45 ± 0.01[a]	0.50 ± 0.05[a]	0.01
Zinc (Zn)	3.38 ± 0.05[d]	3.56 ± 0.05[a]	3.45 ± 0.03[c]	3.51 ± 0.85[b]	0.12

[abcd] means within the same row with different superscripts are significantly different (P<0.05).

Mineral analysis also revealed important distinctions. *Curcuma longa* was the richest in calcium (95.55 mg/100 g), magnesium (90.00 mg/100 g), phosphorus (95.00 mg/100 g), and potassium (85.00 mg/100 g), while *Callotropis procera* had the highest iron (32.75 mg/100 g) and copper (2.00 mg/100 g). *Zyngiber officinale* was notably high in potassium (95.80 mg/100 g). The presence of trace elements such as zinc and manganese in *Curcuma longa* further enhances its nutritional value, a testament to turmeric's mineral richness. Such mineral contributions are critical not only for improving the nutritional profile of cheese but also for enzymatic activity and curd structure formation.

The proximate composition of Bunaji (White Fulani) cow milk recorded in this study agreed with the range reported for indigenous zebu cattle breeds and confirm the suitability of Bunaji milk for cheese production. (Ojedapo *et al.,* 2014), reported that Bunaji milk contained 3.16% protein and 3.78–5.71% range values for fat. More recently, Dauda *et al.,* (2023) reported that White Fulani cows produced milk with 4.52% protein and 2.76% fat, emphasizing that milk composition is influenced by breed and parity. The fat and casein values observed in this study suggested favorable conditions for coagulation and good cheese yield, as also highlighted in earlier dairy studies (Adamu *et al.,* 2022).

The proximate composition of cheeses produced from Bunaji cow milk using these coagulants demonstrated that coagulant type had a significant effect on nutritional quality. Moisture content ranged from 68.50% in *Callotropis* cheese to 73.00% in ginger cheese. The lower moisture in *Callotropis* cheese suggests firmer curd and longer shelf stability, while the higher moisture in ginger cheese indicates softer texture and shorter shelf life. Protein was highest in cheeses made with papaya (19.85%), ginger (21.00%), and turmeric (20.65%), but much lower in *Callotropis* cheese (7.00%). This aligns with the findings of (Adetunji *et al.,* 2008), who reported that *C. papaya* yielded cheese with higher protein retention compared to *C. procera*. Fat content, however, was highest in *Callotropis* cheese (3.65%), while other samples ranged between 1.50–2.25%, showing differences in fat retention during curd formation. Ash content followed a similar trend, with *Callotropis* cheese being highest (2.60%), consistent with its high ash value in the coagulant.

The organoleptic properties of the cheese showed that the coagulants are favourably comparable. However, but the choice of coagulant(s) largely depends on the purpose of production and consumers satisfaction. Soft cheese is prone to early spoilage and that is the advantage of diversifying the coagulants to ensure longer shelf-life of the cheese. The strong flavour and sweetness of *Zyngiber officinale* cheese sample could be linked the release of its nutrients composition and several phytochemical compounds which have biological activities such as antioxidation, antimicrobial and other pharmacological effects (Zhao *et al.,* 2011) during processing. The hard texture and firmness of cheese samples on ginger (*Zyngiber officinale)* and turmeric *(Curcuma longa),* is an indicator for a good storage value and prolong shelf-life. Unlike *Calotropis procera* extracts coagulant that are not suitable for hard cheese production (O'Connor and Tripathi, 1992), because it produces soft cheese with low storage value and shelf life.

The creamy colour and sweet flavour of cheese sample on tumeric (Curcuma longa) could be linked to the nutrients interaction and release during processing. Turmeric is widely used as a spice and colouring agent and is known for its medicinal properties (Luthra *et al.,* 2001). The organoleptic properties of the four coagulants used in this study underscores their comparability and suitability as substitutes as coagulants for use in cheese production. However, the choice of use of the coagulants is subject to the demand of the consumers. In all, the coagulants enhanced the organoleptic properties of cheese from Bunaji cow milk and by extension promotes good health in humans.

Mineral composition of cheese from this study showed that coagulants under investigation best influenced mineral composition of the cheese produced. This could be traced to the nutritional potentials of the selected coagulants, as well as the milk quality of Bunaji cows. (Zamberlin *et al.,* 2012) linked milk mineral composition to animal breed and feed quality; among others. Several reports have been made of K and Ca as leasing minerals in milk (Ahamefule, 2012 and Yoo *et al.,* 2013). Hence, adequate potassium to calcium ratios are important for nutrition and development, ditto to phosphorus, sodium and magnesium due to their roles in various body activities. Magnesium plays an important role in many physiological processes, such as metabolism of proteins and nucleic acids, neuromuscular transmission and muscle contraction, bone growth and blood pressure regulation, Calcium is crucial for bone and teeth formation and functions (Zamberlin *et al.,* 2012). Na functions in the osmo-regulatory status of animals. (Qin, *et al.,* 2009). Following the composition and mineral values recorded in this study, *Carica papaya, Zyngiber officinale* and *Curcumi longa* are justified for use as coagulants in cheese production as they all have required nutritional values required by humans for healthy existence.

Taken together, these results demonstrates that Bunaji milk is nutritionally suitable for cheese-making, but the choice of coagulant plays a critical role in determining the nutrients composition of the resulting cheese. Coagulants such as papaya, ginger, and turmeric produced high-protein cheeses with moderate fat content, making them nutritionally desirable. In contrast, *Callotropis procera* produced soft, mineral-rich cheeses with higher fat but significantly lower protein content. These differences agree with earlier observations that plant-derived coagulants contribute not only enzymes for clotting but also nutrients that influence the final quality of cheese (Dauda *et al.,* 2023).

The findings of this study concluded that Bunaji cow milk contains valuable nutrients, making it suitable for cheese production, and the use of coagulants (*Carica papaya*, *Zyngiber officinale,* and *Curcuma longa*) due to their potentials as feed additive, nutritional and phytochemical composition and tendencies to produce comparatively firmer or even hard cheese.had a significant impact on the proximate and mineral composition of the cheese, producing cheeses with higher protein content and better nutritional quality compared to *Callotropis procera*, which yielded cheese with higher fat but lower protein. The study therefore recommends that aside the common *Calotropis procera* that is commonly used in cheese production, *Carica papaya, Zyngiber officinale*, and *Curcuma longa* has the potential to enhance the nutritional qualities, firmness or even hardness of cheese and as such recommended and encouraged for use in cheese production. While *Callotropis procera* may be used selectively where soft texture is preferred.

Author Contributions

D. O. Okunlola: Investigation, formal analysis, writing—original draft. T. Y. Ojo: Validation, methodology, writing—reviewing. O. I. Oyedokun:—Formal analysis, writing—review and editing. P. O. Oyewole: Investigation, writing—reviewing. A. A. Fasola: Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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