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EFFECT OF PROCESSING VARIABLES ON SOME QUALITY ATTRIBUTES OF SOFT UNRIPENED CHEESE PRODUCED FROM WHITE FULANI CATTLE MILK

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Abstract

This study investigated the effect of processing variables on the quality attributes of soft unripened cheese from white Fulani cattle milk. Response surface methodology based on Box-Behnken design was used in the cheese processing and investigation of the effect of processing variables (boiling temperature, 60-80 ºC; coagulation time, 20-30 min and coagulant volume, 4-6 mL) on soft unripened cheese. The yield, colour (lightness, greenness, and yellowness) and physicochemical properties (pH and total titratable acidity (TTA)), proximate and mineral composition of soft unripened cheese samples were determined using standard methods. The textural (hardness, adhesiveness, cohesiveness, and gumminess) and sensory properties of the samples were also determined. Data were subjected to the analysis of variance and means were separated using Duncan's multiple range test. The yield, moisture, total ash, crude protein, crude fat, crude fibre and total carbohydrate contents of soft unripened cheese samples ranged from 24.90 to 38.84%, 50.04 to 61.13%, 5.46 to 6.61%, 13.04 to 20.82%, 19.02 to 28.38%, 1.78 to 2.69% and 0.95 to 1.64%, respectively. The pH and TTA of soft unripened cheese samples were significantly ($p<0.05$) affected by the boiling temperature, coagulation time and coagulant volume. The increase in the boiling temperature and coagulation time at constant coagulant volume increased the mineral contents of soft unripened cheese. The increase in coagulation time and coagulant volume significantly ($p<0.05$) decreased the textural properties of soft unripened cheese. However, soft unripened cheese can be processed at the processing condition of 80 ºC boiling temperature, 25 min coagulation time and 4 mL coagulant volume.

Keywords: Cheese, boiling temperature, volume, coagulant

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Introduction

Raw milk, the lacteal secretion of ruminants, is regarded as a nutritious food because it is a colloidal suspension of nutrients which are essential for growth and development (Santosh *et al.,* 2018). Due to its short shelf life, milk has to be processed. Cheese is one of the products of milk processing (Omotosho *et al.*, 2011). McSweeney *et al.* (2017) defined cheese as a firm curd of milk solids in which milk fat is entrapped by coagulated protein (casein). Milk from ruminants such as cows, sheep, goats, or buffaloes is often used in the preparation of cheese.

Cheese has a longer shelf life than raw milk and is a concentrated source of protein, fat, minerals, vitamins and essential amino acids (Hussein *et al.,* 2016). Hence, it immensely contributes to the nutritional and health status of man. The consumption of cheese in recent times has continuously risen worldwide (Jeong *et al.*, 2023).

Soft unripened cheese product is also referred to as *Warankashi* in Nigeria, which is made from fresh whole cow milk by the application of a juice extract of Sodom apple leaf (*Calotropis procera*) or pawpaw leaf (*Carica papaya*) (Hussein *et al.*, 2016). In India, soft unripened cheese is commonly known as *Paneer*, in Mexico, it is referred to as *Queso Fresco*, in France, it is called *Fromage Blanc*, in Germany, it is known as *Quark*, while in the United States and parts of Europe, it is generally referred to *Cottage Cheese*

Soft unripened cheese serves as an important and cheap source of protein for the West African populace (Adetunji *et al.*, 2008; Hussein *et al.*, 2016) and it is mainly produced in Nigeria from milk obtained from white Fulani cattle. The traditional processing of soft unripened cheese which is still done using indigenous knowledge passed from one generation to another, involves the use of *Calotropis procera* as the source of the coagulating enzyme. The coagulating enzyme is usually added in small amounts to give strength to the curd.

Coagulation is an important unit operation in cheese making and it is crucial to the quality of the final product (Ong *et al.*, 2011). Milk coagulation property is a measure of milk process ability for cheese making. It is the ability of milk to react with a coagulant (during cheese making) to form a curd with proper consistency at an optimal processing time, and being able to present good ability for syneresis (Beux *et al.*, 2017). Some factors that influence the coagulating property of milk include the temperature of milk, the type and concentration of the coagulating enzyme, and the duration of coagulation (Beux *et al.* 2017). These factors affect the final quality (chemical composition, physicochemical and textural properties, among others) of cheese (Adegoke *et al.*, 1992; Belewu *et al.*, 2005; Adetunji and Salawu, 2008; Adetunji *et al.*, 2008; Hussein *et al.*, 2016).

Previous studies have reported on some aspects of coagulation during soft unripened cheese production. Adetunji and Babalobi (2011) study the comparison of the nutritional and microbial qualities of *warankashi* from the extracts of *Calotropis procera* and *Cymbopogon citratus*. Abebe and Emire (2020) study the effects of dried *Calotropis procera* extract on toxicity, milk-clotting activity, physicochemical, textural and microbial qualities of soft unripened cheese.

Furthermore, Lawale (2018), although he studied the effect of processing conditions (temperature, time and quantity of coagulant) on certain attributes of soft unripened cheese (*warankashi*) produced from cow milk, used a different method of coagulant extraction from the one being used by the traditional processors. Many of these studies were limited, in terms of the effects of the traditional processing variables on the quality of soft unripened cheese. For instance, Chikpah *et al.* (2014) did not vary the coagulant's concentration and time, which have been reported by other authors such as Lawale (2018) and Adamu *et al.* (2020) to affect the quality of soft cheese. The investigation of Adamu *et al*. (2020) was limited to the effects of processing variables on the yield of soft unripened cheese. There is limited research on the processing variables, particularly the optimal quantity of coagulant and the extraction method of *Calotropis procera* for producing soft unripened cheese from White Fulani cattle milk using the traditional processing method. The objective of this study is to determine the effect of processing variables (boiling temperature, coagulation time and coagulant volume) on some quality attributes of soft unripened cheese produced from white Fulani cattle milk.

Materials and methods

Materials

Fresh milk of white Fulani cow was obtained from the ruminant farm of the Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB). Fresh leaves of *Calotropis procera* were obtained from the Directorate of University Farms, FUNAAB, Nigeria.

Preparation of Calotropis procera extract

Extract of *Calotropis procera* was prepared by the methods described by Ogunlade *et al.* (2020). About 50 g of leaves were weighed and washed with potable water. The leaves were carefully sliced with a stainless-steel knife and then crushed using a laboratory mortar and pestle. The crushed product was further sieved using a filter paper (Whatman No.1). The filtrate was collected and used as coagulant in soft unripened cheese processing.

Processing of soft unripened cheese

The method described by Chikpah *et al.* (2014) was used in the processing of soft unripened cheese. 1000 mL of fresh cow milk was pasteurized at 70 ºC for 15 min. The cheese was prepared by heating (60 - 80 ºC) the pasteurized cow milk using 4 - 6 mL of vegetable rennet extract of Sodom apple. It was carefully observed till coagulation commenced. Coagulation continued for 20 – 30 min to inactivate the plant enzyme and facilitate whey expulsion. Small conical raffia baskets were used to mould the cheese to a characteristic shape and also for whey drainage.

Experimental design

Three independent variables: boiling temperature (X_1), coagulation time (X_2), and coagulant volume (X_3) were studied. Three levels of each of the three independent variables were chosen for the study, based on the report from preliminary experiments.

Preliminary experiments for this study revealed that the lowest quantity of *Calotropis procera* extract for the coagulation of 1000 mL of milk was at 4 mL. Cheese production was not achieved at 2 – 3 mL of extract for 1000 mL of milk. The onset of coagulation occurred at 60 ºC, hence the use of 60 ºC as the lowest temperature.

Beux *et al.* (2017) stated that the main factors that influence the coagulating property of milk include the temperature of milk, type and concentration of coagulating enzyme, and duration of coagulation. Hence the use of the three independent factors (boiling temperature, coagulation time and coagulant volume).

The three levels of each of these independent variables were boiling temperature (X_1) of (-1, 0, 1); coagulation time (X_2) of (-1, 0, 1), and coagulant volume (X_3) of (-1, 0, 1). The coded and the actual values for the independent variables are shown in Table 1. Box-Behnken design was used to generate a total number of seventeen experimental runs using Design expert 13.0 as shown in Table 2.

Table 1. Coded values of the independent variables

Variables	Codes		
	-1	**0**	**+1**
Boiling temperature (ºC)	60	70	80
Coagulation time (min)	20	25	30
Quantity of coagulant (mL)	4	5	6

Table 2. Experimental design showing the processing variables using Response Surface Methodology (RSM)

Experimental runs	**Process variables**		
	Boiling temperature (ºC)	**Coagulation time (min)**	**Coagulant volume (mL)**
1	60	20	5
2	70	20	6
3	80	25	6
4	70	30	6
5	60	25	6
6	70	25	5
7	70	25	5
8	80	20	5
9	70	25	5
10	70	25	5
11	60	30	5
12	60	25	4
13	70	30	4
14	70	25	5
15	80	30	5
16	70	20	4
17	80	25	4

Proximate composition of raw milk and soft unripened cheese

Moisture content was determined using a hot air oven (AOAC 952.08, 2016), the total ash was carried out using the gravimetric method (AOAC 930.30, 2016), the sample was then ashed by placing it in pre-heated muffle furnace at 600 ˚C for 6 h and until constant weight was achieved. Crude protein was determined using the Kjeldahl method (AOAC 992.23, 2016), crude fat was determined using the Soxhlet extraction method (AOAC 948.15, 2016) and crude fibre was determined through extraction with petroleum ether (AOAC 985.29, 2016) while total carbohydrate was determined using the difference method.

Cheese yield content

The cheese yield was calculated according to Ojedapo *et al.* (2014)

$$\text{Yield of cheese (\%)} = \frac{\text{weight of cheese}}{\text{weight of milk used}} \times 100 \qquad (1)$$

where:

weight of cheese= mass of the final cheese after pressing and draining (kg)

weight of milk used= total weight of raw milk used for cheese making (kg)

Physicochemical properties

Determination of total titratable acidity

This method is described by AOAC (2016). Ten grams of the soft unripened cheese sample was dissolved in 30 mL of distilled water in a beaker and stirred. The mixture was then filtered into a 100 mL standard volumetric flask. The filtrate was made up to 100 mL. Ten millilitres of the filtrate was pipetted into a beaker and one drop of phenolphthalein was added. The mixture was then titrated against the standard 0.01 N sodium hydroxide solution until a light pink colour was attained. The calculation of the total titratable acidity was done according to equation 2.

$$\text{Titratable acidity} = \frac{N\,(NaOH) \times titre\ value \times lactic\ acid\ value}{weight\ of\ sample\ (g)} \times 100 \qquad (2)$$

Where: N = normality of NaOH (0.01); Lactic acid value = 0.09

Determination of pH

The method described by AOAC (2016) was used. Ten grams of the soft unripened cheese sample was dissolved in 30 mL of distilled water in a beaker and stirred. The mixture was filtered into a 100 mL standard volumetric flask. The filtrate was made up to 100 mL. The pH electrode was calibrated by the use of prepared buffer solutions of accurately known pH (pH 4 and pH 9) and then placed into the sample. The electrode was allowed to stabilize for few minutes. The pH value of the sample was taken afterwards.

Mineral composition of soft unripened cheese

Calcium, magnesium, phosphorus and potassium contents were determined according to the method described by Okafor *et al.* (2017). The determination was done in three phases: sample preparation, sample digestion, and atomic absorption spectrophotometer (AAS) analysis. Standard serial concentrations of pure forms of the minerals were prepared to standardize the AAS before reading the concentration of minerals. Soft unripened cheese sample (0.67 g) was weighed into a glass beaker and 50 mL of nitric acid was added to it. The solution was heated gently in a fume cupboard with a Bunsen burner. The HNO_3 fumes were allowed to escape gradually until no more fume was noticed. This indicated the end of the digestion. The digested samples were filtered into a 50 mL standard flask, made up to volume with distilled water and prepared for AAS analysis. A standard curve was obtained for each of the minerals using the serially diluted concentration standards, with an appropriate lamp particular to a given mineral which was mounted on the AAS. After obtaining the standard curve at a particular wavelength, the digested samples in the container were drawn into the AAS for analysis. The lamps and individual wavelengths of the mineral element that were analysed included: Calcium (Ca lamp; 317 nm), magnesium (Mg lamp; 279 nm), phosphorus (P lamp; 213 nm), and potassium (K lamp; 766 nm).

Colour properties of soft unripened cheese

The method described by Tougan *et al.* (2021) was used. To measure the colour of soft unripened cheese, Minolta chroma meter (CR-410 Japan) was used based on (CIE) L*, a* and b* scale. The instrument was calibrated by covering a zero-calibration mask followed by a white calibration plate. Thereafter, the colour of soft unripened cheese samples was analysed by placing each of the samples on a Petri dish, and then the image was captured of the samples. The colour attributes such as lightness (L*), greenness (-a*), and yellowness (b*) were measured.

Textural properties of soft unripened cheese

Puncture test was performed on the soft unripened cheese samples using a universal testing machine (Model: 0500-10080 Capacity: 100 kN, Lancashire, England). Each test cycle was completed with a 6 mm diameter puncture probe. The parameters for the test included a pre-load speed of 60.000 mm/min. The distance was set at 50 % strain, a trigger point at 0.200 N, and an acquisition rate at 102 mm/min. The puncture test was run in two cycles for all the seventeen soft unripened cheese samples and the following parameters were determined: hardness, adhesiveness, cohesiveness, and gumminess (Tunick, 2000).

Sensory qualities of soft unripened cheese

The clearance for the study was obtained from the Department of Food Science and Technology, Federal University of Agriculture, Abeokuta (FUNAAB) for sensory evaluation. The cheese samples were subjected to in-house consumer acceptability using 50 panelists. Twenty-five of the panelists were female while twenty-five were male. Their age ranged from 18- 40 years old. The panelists were semi-trained through verbal instruction prior to the sensory evaluation. They were briefed on the attributes to be assessed, (including colour, aroma, taste, overall acceptability), and guided on the use of the Hedonic scale to ensure consistency during evaluation. A nine-point Hedonic scale was used to determine the degree of likeness, with 1 representing the least score (Dislike extremely) and 9 the highest score (Like extremely). The samples were coded with three digits random numbers in odourless plastic plates with a random order of serving. The sample were rated for colour, aroma, taste, and overall acceptance among the panelist as described by Iwe (2010).

Statistical analysis

Each analysis was carried out in three replications. Data obtained were subjected to statistical analysis and were expressed as means, analysis of variance (ANOVA) was determined using SPSS version 21.0 and the separation of the mean values was evaluated at $p \leq 0.05$, using Duncan's multiple range test.

Results and Discussion

Proximate composition of raw milk of white Fulani cattle

The proximate composition of the raw milk used for this study was 84.11%, 0.92%, 3.92%, 4.21%, and 6.84% for the moisture, total ash, crude protein, crude fat, and total carbohydrate, respectively. Moisture contents of 81.67 – 87.2% have been reported for raw milk obtained from cattle (Dandare *et al.*, 2014; Lambrini *et al.*, 2021). Similar value of 0.90% was obtained for total ash content by Dandare *et al.* (2004) while Lambrini *et al.* (2021) reported lower values of 0.52% and 0.70%, respectively. The crude protein content (3.92%) obtained in this study was higher than the value of 3.50% reported by and Lambrini *et al.* (2021), respectively. Lambrini *et al.* (2021) reported lower values for crude fat and total carbohydrate. Causes of variations in the proximate composition of the milk may be due to the breed, age, nutrition, among others (Kheowsri *et al.*, 2023).

Proximate composition of soft unripened cheese

The proximate composition of soft unripened cheese is presented in Table 3. Moisture content of food is an indicator of its water content and shelf stability. One of the major factors that can affect the moisture content of soft unripened cheese is the initial moisture content of the milk used during cheese processing. The moisture content of soft unripened cheese obtained in this study (50.04 - 61.13%) is similar to the value of 50.1 - 51.0% reported by Omotosho *et al.* (2011). However, this result is higher than the values of 45.12% - 58.30% reported by Hussein *et al.* (2016), but lower than the values of 62.50% and 63.56% obtained by Adetunji *et al.* (2008) and Adetunji and Babalobi, (2011), respectively. This may be due to variations in the types of coagulant used in the different studies. The ash content is an indicator of the total amount of minerals present within a food. It represents the inorganic residue (minerals) remaining after ignition and complete oxidation of organic matter (Motegaonkar and Salunke, 2012). The result reported in this study (5.46% - 6.61%) is higher than the reports of Belewu and Morakinyo (2009) and Olorunisomo and Adewumi (2016), and this may be due to differences in the processing methods.

Crude protein refers to a group of polypeptide structures made up of one or more extended chains of amino acids. Proteins primarily help to build and repair tissues (Shiekhi *et al.*, 2023). The increase in the crude protein content of soft unripened cheese may be linked to the coagulation of more casein present in the milk when more coagulant was added (Ali *et al.*, 2021).

Table 3. Proximate composition of soft unripened cheese.

Experimental Runs	Moisture Content (%)	Total Ash (%)	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	CHO (%)
1	50.67 ± 0.21^{e}	5.91 ± 0.03^{f}	15.47 ± 0.11^{bcd}	25.87 ± 0.13^{ji}	1.89 ± 0.14^{ab}	0.19 ± 0.03^{b}
2	61.13 ± 0.16^{j}	5.55 ± 0.15^{abc}	18.28 ± 0.06^{e}	19.02 ± 0.20^{a}	1.99 ± 0.05^{abc}	0.95 ± 0.08^{a}
3	53.33 ± 1.16^{d}	5.66 ± 0.09^{bcd}	16.47 ± 0.38^{cd}	25.90 ± 0.05^{gh}	2.19 ± 0.03^{bcd}	1.37 ± 0.05^{de}
4	55.69 ± 0.07^{f}	5.50 ± 0.05^{ab}	15.55 ± 0.07^{bcd}	21.52 ± 0.04^{b}	1.97 ± 0.08^{ab}	1.11 ± 0.02^{b}
5	56.31 ± 0.34^{g}	5.81 ± 0.07^{def}	15.36 ± 0.29^{bc}	24.45 ± 0.30^{d}	1.78 ± 0.30^{a}	1.19 ± 0.05^{bc}
6	50.84 ± 0.25^{b}	5.85 ± 0.08^{ef}	16.39 ± 0.07^{cd}	25.81 ± 0.09^{gh}	1.99 ± 0.06^{abc}	1.32 ± 0.07^{d}
7	51.40 ± 0.38^{bc}	5.49 ± 0.10^{ab}	16.62 ± 0.21^{cd}	25.90 ± 0.22^{gh}	2.17 ± 0.07^{bcd}	1.64 ± 0.14^{f}
8	54.49 ± 0.01^{e}	5.46 ± 0.02^{a}	16.87 ± 0.26^{d}	23.81 ± 0.26^{c}	1.78 ± 0.23^{a}	1.44 ± 0.10^{e}
9	50.04 ± 0.11^{a}	5.66 ± 0.10^{bcd}	16.38 ± 0.05^{cd}	25.19 ± 0.11^{e}	2.14 ± 0.03^{bcd}	1.28 ± 0.05^{cd}
10	52.98 ± 0.90^{d}	5.91 ± 0.31^{f}	20.82 ± 0.20^{f}	27.04 ± 0.08^{k}	2.31 ± 0.26^{cd}	1.20 ± 0.04^{bc}
11	51.20 ± 0.21^{b}	5.72 ± 0.10^{cde}	16.37 ± 0.35^{cd}	25.30 ± 0.12^{ef}	2.08 ± 0.04^{abc}	1.27 ± 0.06^{cd}
12	55.01 ± 0.03^{e}	5.88 ± 0.06^{ef}	14.83 ± 0.09^{b}	25.61 ± 0.12^{fg}	1.91 ± 0.13^{ab}	1.19 ± 0.03^{bc}
13	51.35 ± 0.16^{b}	5.85 ± 0.12^{ef}	15.64 ± 0.04^{bcd}	26.51 ± 0.64^{ij}	1.91 ± 0.35^{ab}	1.15 ± 0.01^{b}
14	51.98 ± 0.11^{c}	5.81 ± 0.04^{def}	16.29 ± 0.06^{cd}	26.23 ± 0.04^{hi}	2.41 ± 0.08^{de}	1.36 ± 0.02^{de}
15	58.33 ± 0.49^{i}	6.30 ± 0.12^{g}	13.04 ± 0.07^{a}	21.76 ± 0.23^{b}	1.95 ± 0.09^{ab}	1.17 ± 0.05^{bc}
16	52.98 ± 0.09^{d}	5.91 ± 0.03^{f}	20.82 ± 0.20^{f}	27.04 ± 0.08^{k}	2.31 ± 0.26^{cd}	1.20 ± 0.04^{bc}
17	57.58 ± 0.04^{h}	6.61 ± 0.22^{h}	15.54 ± 0.03^{bcd}	28.38 ± 0.39^{l}	2.69 ± 0.16^{e}	1.13 ± 0.03^{b}

Mean values with different superscripts across the column are significantly different ($p < 0.05$). CHO-Carbohydrate

The crude protein content reported in this study (13.04% - 20.82%) is within the range of values of 14.59% - 18.77%, 14.74% - 20.13%, 14.04% - 16.91% and 17.55% - 19.37% reported by Abdulkareem (2013), Ojedapo *et al.* (2014), Gonzalez *et al.* (2018) and Abebe and Emire (2020), respectively on soft ripened cheese. However, the result is lower than the values of 31.60% - 33.84%, 26.37% - 38.13% and 21.60% reported by Adetunji *et al.* (2008), Belewu and Morakinyo (2009) and

Olorunisomo and Adewumi (2016), respectively but higher than that of Badmos and Ajiboye (2012). The result of this study revealed that when the coagulant volume was kept constant, as the boiling temperature and coagulation time increased, the crude protein decreased. This may be due to the denaturation of the protein structure by the increased boiling temperature (Ali *et al*., 2021).

The crude fat content (19.02 % - 28.38 %) is similar to the result by Adetunji *et al.* (2008) who reported high fat content in soft unripened cheese due to the high coagulation strength in *Calotropis procera*. The main effect of the boiling temperature had a negative effect on the crude fat content of soft unripened cheese and this may be due to a strengthened gel network at higher coagulation temperature which leads to a greater loss of fat in the whey (Ong *et al.*, 2011). It could also be attributed to the direct effect of the boiling temperature on the physical properties of the fat globule (Lopez *et al.*, 2006). When the boiling temperature and coagulation time increased at a constant coagulant volume, the fat content of soft unripened cheese decreased. This may be linked to the fact that, with time, high temperature induces the aggregation of fat globules (Lopez *et al.*, 2006); this aggregation and coalescence of fat globules may allow the fat to form pools that will subsequently leak out from the protein matrix during cheese production (Richoux *et al.*, 2008). The crude fibre content ranged from 1.78 - 2.60%. The carbohydrate content recorded herein (0.95% - 1.64%) is similar to the values reported by Olorunisomo and Ikpiyang (2012).

Yield and physicochemical properties of soft unripened cheese

The effect of process variables on yield and physicochemical properties of soft unripened cheese is presented in Table 4. Cheese yield, the amount of cheese produced in grams, from 1 L of milk can be affected by the quality of milk which in turn is influenced by factors such as age, stage of lactation, nutrition of the animal seasonal variations, and processing conditions (Omotosho *et al.*, 2011; Akinloye and Adewumi 2014). The range of values for yield (24.90 – 38.84 %) in this study is similar to 25.59% and 32.75% reported by Akinloye and Adewumi (2014) and Omotosho *et al.* (2011), respectively. The observed increase in the boiling temperature which led to a decrease in cheese yield had been reported by Adamu *et al.* (2020). This could be due to the fact that the activation energy of the reaction was greater than the heat of formation of cheese, which subsequently led to bond breakage thereby causing a decrease in yield (Adamu *et al.*, 2020). The decrease in cheese yield as the coagulation time increased agreed with the findings of Chikpah *et al.* (2014) and Adamu *et al.* (2020). This could be due to the increased volume of whey as the coagulation period increased. Whey consists of water and soluble milk substances such as proteins, minerals, lactose, and vitamins (Moatsou and Moschopoumou, 2021). An increase in the coagulant volume led to an increase in cheese yield. An increase in the coagulation time and the coagulant volume led to a decrease in yield, this could be because, with time, as the reaction occurs, the concentration of raw milk (the reactant) decreases due to coagulation. When the milk is used up, the energy within the reaction medium (coagulant) accumulates with time and as the heat energy exceeds the heat of formation of cheese, the existing bonds begin to break, thereby causing a decrease in cheese yield (Adamu *et al.*, 2020).

Table 4. Yield and physicochemical properties of soft unripened cheese

Experimental runs	Yield (%)	pH	TTA (%)
1	32.27	6.40 ± 0.00^{bc}	0.13 ± 0.01^{a}
2	29.68	6.83 ± 0.06^{h}	0.14 ± 0.01^{a}
3	33.17	6.70 ± 0.06^{g}	0.17 ± 0.01^{c}
4	30.48	6.80 ± 0.00^{h}	0.17 ± 0.01^{c}
5	38.84	6.67 ± 0.06^{fg}	0.18 ± 0.01^{c}
6	25.60	6.50 ± 0.00^{d}	0.18 ± 0.01^{c}
7	25.90	6.50 ± 0.00^{d}	0.15 ± 0.01^{abc}
8	29.98	6.60 ± 0.00^{e}	0.13 ± 0.00^{a}
9	25.10	6.43 ± 0.06^{b}	0.18 ± 0.02^{c}
10	24.90	6.63 ± 0.06^{ef}	0.17 ± 0.02^{bc}
11	28.09	6.43 ± 0.06^{c}	0.15 ± 0.01^{ab}
12	27.09	6.30 ± 0.00^{a}	0.18 ± 0.02^{c}
13	28.29	6.40 ± 0.00^{bc}	0.18 ± 0.01^{c}
14	26.29	6.70 ± 0.00^{g}	0.18 ± 0.01^{c}
15	28.88	6.60 ± 0.01^{e}	0.14 ± 0.01^{a}
16	30.68	6.37 ± 0.06^{b}	0.17 ± 0.02^{bc}
17	27.19	6.40 ± 0.00^{bc}	0.18 ± 0.01^{c}

Mean values with different superscripts across the column are significantly different ($p<0.05$).

Total titratable acidity (TTA) and pH are interrelated in terms of acidity; however, they have a different impact on food quality (Sadler and Murphy, 2010). It was observed that the pH and TTA of the soft unripened cheese increase thereby tending towards slight acidity. The total acid available to react with sodium hydroxide solution during titration is defined as titratable acidity while pH gives a measure of the hydrogen ion concentration in food. The total titratable acidity reported in this study (0.13%-0.18%) agrees with the values of 0.13%-0.14% reported in the study of Tougan *et al.* (2021) on *wagashi*- a soft unripened cheese common in Benin Republic. It is also similar with the findings of Belewu and Belewu, (2007) and Akinloye and Adewumi (2014). The pH values observed in this study (6.30- 6.33) are higher than 4.50 - 5.10 and 4.21- 5.10 reported by Olorunisomo and Adewumi (2016) and Hussein *et al.* (2016), respectively. This might be due to different types of coagulants used in the processing of soft unripened cheese. The addition of more coagulant during soft unripened cheese production caused an increase in titratable acidity and a decrease in pH, and this agrees with the study of Ali *et al.* (2021).

Mineral composition of soft unripened cheese

The mineral composition of soft unripened cheese is presented in Table 5. The calcium, phosphorus, potassium and magnesium contents of soft unripened cheese varied from 127.92 to 187.76 mg/100g, 108.57 to 153.34 mg/100g, 47.63 to 61.30 mg/100g40.48 to 61.13mg/100g, respectively. These values are higher than the values reported by Omotosho *et al.* (2011), but lower than those of Okorie and Adedokun (2013) and Ogunlade *et al.* (2019). The variation may be attributed to differences in the processing conditions. For example, Okorie and Adedokun (2013) produced soft unripened cheese *(warankashi*) from blends of cow and Bambara nut milk. Similar calcium contents were reported by Ibhaze *et al.* (2017) and Feeney *et al.* (2021). Calcium is an essential mineral element for the vulnerable group such as women and children, as it is necessary for bone and teeth development (Sette *et al.*, 2013).

Table 5. Mineral composition of soft unripened cheese

Experimental Runs	Ca (mg/100g)	P (mg/100g)	K (mg/100g)	Mg (mg/100g)
1	151.07±7.20^{b}	108.57±0.98^{a}	56.82±1.07^{ef}	61.06±1.09^{g}
2	149.81± 7.14^{b}	143.24±5.26^{g}	49.93±0.70^{abc}	54.01±1.25^{e}
3	178.32±5.93^{d}	142.42±3.15^{g}	51.07±0.90^{bc}	56.86±2.27^{f}
4	169.27±8.06^{c}	136.65±3.41^{f}	55.62±2.39^{ef}	42.11±1.16^{ab}
5	151.57±3.75^{b}	132.29±2.81^{f}	61.30±0.82^{g}	49.41±0.69^{d}
6	162.91±4.93^{c}	131.71±2.05^{ef}	51.03±1.16^{bc}	44.57±1.31^{c}
7	162.34±2.99^{c}	131.23±2.05^{ef}	51.09±1.19^{bc}	44.10±1.03^{bc}
8	127.92±5.03^{a}	121.93±1.94^{cd}	47.63±1.99^{a}	40.48±1.30^{a}
9	163.42±3.60^{c}	132.26±1.73^{f}	51.46±2.04^{bc}	43.78±0.69^{bc}
10	162.20±3.68^{c}	131.66±1.97^{ef}	51.20±2.03^{bc}	43.43±0.60^{bc}
11	170.75 ±3.37^{cd}	121.12±0.53^{cd}	52.25±0.43^{cd}	45.00±1.89^{c}
12	178.72±6.63^{d}	126.20±4.37^{de}	54.27±0.92^{de}	45.30±1.88^{c}
13	179.16±7.21^{d}	147.83±3.04^{h}	56.32±1.13^{ef}	50.07±0.26^{d}
14	162.72±2.76^{c}	132.10±2.02^{f}	50.67 ±1.49^{bc}	43.42± 0.40^{bc}
15	152.34±2.22^{b}	153.34±4.70^{i}	57.25 ±1.88^{f}	50.03±0.17^{d}
16	187.76±4.17^{e}	119.51±0.60^{c}	58.13±1.99^{f}	51.02±0.83^{d}
17	146.84±2.33^{b}	113.97±5.33^{b}	48.69±1.50^{ab}	61.13±1.04^{g}

Mean values with different superscripts across the column are significantly different ($p < 0.05$); Ca-Calcium, P-Phosphorus, K-Potassium, Mg-Magnesium.

Colour properties of soft unripened cheese

The colour properties of soft unripened cheese are shown in Table 6. The lightness value ranged from 76.69 – 93.63. The lightness of soft unripened cheese decreased with an increase in boiling temperature and coagulation time. This could be attributed to the fact that soft unripened cheese was subjected to longer processing (coagulation) time thereby resulting in the absorption of whey which reduces the ability of casein to reflect white light (Johnson, 2009). As the boiling temperature and coagulant volume increased, there was a decrease in the lightness of soft unripened cheese. This could be due to the green pigment present in *Calotropis procera* (Abebe and Emire, 2020). The greenness value increased with the increase in coagulation time and coagulant volume at constant boiling temperature. Chikpah *et al.* (2014) had reported that the green colour of *Calotropis procera* leaves influenced the colour of soft unripened cheese. The yellowness value ranged from

12.86 – 25.33. The increase in boiling temperature and coagulation time led to an increase in the yellowness when the coagulant volume was kept constant. This could be attributed to the onset of thermal degradation of the food nutrients, as well as Maillard reaction. These reactions sometimes lead to chemical modifications such as colour and flavour change (Kaminarides *et al.*, 2015). This agrees with the study of Tougan *et al.* (2021) that increased time affected the colour of cream and cottage cheese, resulting in more yellow cheese curds.

Table 6. Colour properties for soft unripened cheese

Experimental runs	L^*	a^*	b^*
1	91.34 ± 0.06[fg]	-1.05 ± 0.04[def]	20.35 ± 0.40[fg]
2	90.76 ± 0.54[f]	-5.63 ± 0.02[b]	15.31 ± 0.10[b]
3	86.21 ± 1.29[c]	-5.90 ± 0.45[b]	22.29 ± 0.06[i]
4	88.11 ± 1.99[d]	-3.18 ± 0.07[c]	19.98 ± 0.04[f]
5	91.78 ± 0.68[fg]	5.36 ± 0.12[g]	15.99 ± 0.57[c]
6	90.14 ± 0.85[ef]	-3.26 ± 0.07[c]	18.45 ± 0.06[d].
7	90.12 ± 0.06[ef]	-2.92 ± 0.08[cd]	20.83 ± 0.08[gh]
8	88.65 ± 0.02[de]	-0.76 ± 1.04[ef]	25.90 ± 0.64[i]
9	88.73 ± 0.04[de]	-1.12 ± 0.27[def]	25.76 ± 0.06[ji]
10	90.25 ± 0.10[ef]	-2.90 ± 0.09[cd]	20.89 ± 0.04[h]
11	91.79 ± 0.18[fg]	0.43 ± 0.16[f]	15.06 ± 0.03[b]
12	93.63 ± 0.21[h]	-0.27 ± 0.02[ef]	12.86 ± 0.05[a]
13	76.69 ± 2.21[a]	-8.44 ± 0.42[a]	21.96 ± 0.45[i]
14	88.93 ± 0.03[de]	-3.34 ± 0.05[c]	18.54 ± 0.06[d]
15	84.72 ± 0.89[b]	-1.76 ± 0.11[cde]	25.33 ± 0.57[j]
16	92.61 ± 0.19[gh]	-3.27 ± 0.43[c]	18.83 ± 0.16[de]
17	90.16 ± 1.12[ef]	-0.65 ± 0.24[ef]	19.30 ± 0.19[e]

Mean values with different superscripts across the column are significantly different ($p < 0.05$); L*: Lightness, a*: Redness, b*: Yellowness

Textural properties of soft unripened cheese

Texture is an important parameter in the evaluation of cheese quality. The mean values for hardness, adhesiveness, cohesiveness and gumminess ranged from 0.82 to 1.91 N, 0.09 to 1.02 N·s, 0.26 to 0.56 and 0.25 to 0.93 N, respectively as shown in Table 7. Hardness is defined as the force required for the compression of cheese samples (up to 30%) of their original height (Ali *et al.*, 2021). The hardness of the soft unripened cheese increased at a constant volume of coagulant when the boiling temperature and coagulation time increased. Yuanrong (2016) had earlier stated that low boiling temperature and short processing time during soft cheese production results in a watery-like cheese curd. This may also be linked to the fat content of the soft unripened cheese. Faber *et al.* (2017) reported that when the fat content of cheese decreases, the hardness increases. At constant coagulation time, the hardness decreased with increase in boiling temperature and volume of coagulant. This observation is in contrast with the findings of Ali *et al.* (2021), who reported that the addition of more coagulant of cottage cheese increased its hardness. This may be attributed to the interaction effect of boiling temperature with the volume of coagulant. The stress, necessary to pull up the measure probe after the 50% compression is termed as the adhesiveness (Ivanov *et al.*, 2021). At constant volume of coagulant, increase in boiling temperature and coagulant time increased the adhesiveness of soft unripened cheese. The results obtained from this study showed that the lower the value of adhesion, the less the energy required to masticate the cheese in the mouth. The results are similar to that obtained by Belewu and Belewu (2007). Cohesiveness is defined as the work required to overcome the internal bonding of the material. It is also a measure of the deformation of cheese before it breaks (Rekha and Vijayalakshmi, 2013). At constant boiling temperature, the increase in coagulation time and coagulant volume led to an increase in the cohesiveness of the soft unripened cheese. This could be due to a variation in processing conditions and proteolysis of casein to compounds that are very soluble in water and do not contribute to the protein network responsible for the cheese rigidity (Lawale, 2018). The energy required to disintegrate a semisolid food to a state ready for swallowing is gumminess. It was observed that the increase in boiling temperature and boiling time led to an increase in gumminess of soft unripened cheese at a constant coagulant volume. This could be attributed to the progressive increase in hardness and cohesiveness (Gonçalves and Cardarelli, 2020).

Table 7. Textural properties of soft unripened cheese

Experimental runs	Hardness (N)	Adhesiveness (N.s)	Cohesiveness	Gumminess (N)
1	1.65 ± 0.15^{fg}	0.92 ± 0.20^{ef}	0.49 ± 0.07^{cde}	0.79 ± 0.04^{fgh}
2	1.80 ± 0.22^{gh}	0.19 ± 0.29^{ab}	0.50 ± 0.08^{cde}	0.87 ± 0.04^{hi}
3	0.82 ± 0.01^{a}	0.55 ± 0.06^{cd}	0.40 ± 0.06^{bc}	0.33 ± 0.05^{ab}
4	1.17 ± 0.03^{bc}	0.75 ± 0.07^{de}	0.56 ± 0.02^{e}	0.65 ± 0.01^{e}
5	0.95 ± 0.10^{a}	1.02 ± 0.00^{f}	0.26 ± 0.030^{a}	0.25 ± 0.06^{a}
6	1.91 ± 0.18^{h}	0.21 ± 0.10^{ab}	0.49 ± 0.02^{cde}	0.93 ± 0.13^{i}
7	1.26 ± 0.07^{cd}	0.10 ± 0.13^{a}	0.53 ± 0.12^{de}	0.68 ± 0.19^{ef}
8	1.62 ± 0.23^{fg}	0.12 ± 0.05^{a}	0.50 ± 0.10^{cde}	0.78 ± 0.05^{fgh}
9	1.30 ± 0.01^{cd}	0.12 ± 0.01^{a}	0.48 ± 0.01^{cde}	0.70 ± 0.01^{efg}
10	1.72 ± 0.05^{fgh}	0.19 ± 0.00^{ab}	0.52 ± 0.02^{de}	0.80 ± 0.01^{fghi}
11	1.39 ± 0.11^{de}	0.65 ± 0.33^{cd}	0.41 ± 0.04^{bc}	0.58 ± 0.10^{de}
12	1.20 ± 0.09^{bcd}	1.00 ± 0.00^{f}	0.29 ± 0.01^{a}	0.35 ± 0.04^{ab}
13	1.01 ± 0.08^{ab}	0.09 ± 0.04^{a}	0.49 ± 0.00^{cde}	0.49 ± 0.04^{cd}
14	1.32 ± 0.04^{cd}	0.18 ± 0.01^{ab}	0.41 ± 0.01^{bc}	0.83 ± 0.05^{ghi}
15	1.56 ± 0.14^{ef}	0.29 ± 0.04^{ab}	0.29 ± 0.04a	0.45 ± 0.10^{bc}
16	1.40 ± 0.03^{de}	0.43 ± 0.01^{bc}	0.44 ± 0.00^{bcd}	0.61 ± 0.01^{de}
17	1.32 ± 0.07^{cd}	0.15 ± 0.16^{a}	0.34 ± 0.01^{ab}	0.45 ± 0.03^{bc}

Mean values with different superscripts across the column are significantly different ($p < 0.05$).

Sensory quality of soft unripened cheese

The effect of process variables on the sensory quality of soft unripened cheese is presented in Table 8. The perception of the sensory characteristics of food results from the stimulation of human senses. The colour, aroma and taste ranged from 1.48

to 8.06, 1.54 to 8.18 and 1.62 to 8.20, respectively. Soft unripened cheese produced from boiling temperature, coagulation time and coagulant volume at 60 ºC, 30min and 5mL had the lowest colour, aroma and taste while soft unripened cheese produced from boiling temperature, coagulation time and coagulant volume at 75 ºC, 25min and 5mL had the highest. The overall acceptability expresses how the consumers or panelists generally accept the product. The overall acceptability ranged from 2.00 to 9.52. Soft unripened cheese produced from boiling temperature, coagulation time and volume of coagulant at 80 ºC, 25min and 4mL had the highest overall acceptability. Soft unripened cheese samples were less accepted when the coagulant volume increased, and this may be due to the bitter taste attributed to the addition of more coagulant thereby making the cheese samples be rated lower by the panelist (Abebe and Emire, 2020). The fact that soft unripened cheese samples were most acceptable at increased boiling temperature and reduced coagulant volume, may be due to the production of firmer curds produced through the increased boiling temperature.

Table 8. Sensory qualities of soft unripened cheese

Experimental runs	Colour	Aroma	Taste	Overall Acceptability
1	2.62 ± 1.47^{bc}	3.04 ± 1.47^{cd}	2.30 ± 1.51^{b}	8.88 ± 0.45^{b}
2	2.40 ± 1.03^{bc}	2.36 ± 1.17^{b}	2.26 ± 1.08^{b}	3.74 ± 0.45^{h}
3	6.90 ± 2.09^{g}	6.38 ± 2.05^{f}	6.72 ± 1.91^{f}	4.04 ± 0.44^{f}
4	4.94 ± 1.57^{de}	3.68 ± 0.96^{ef}	3.68 ± 0.96^{c}	2.00 ± 0.24^{hi}
5	2.86 ± 1.49^{c}	2.78 ± 1.49^{bcd}	2.66 ± 1.53^{b}	5.44 ± 0.54^{e}
6	7.40 ± 1.36^{gh}	7.44 ± 1.26^{i}	7.64 ± 0.99^{g}	6.14 ± 0.61^{d}
7	7.84 ± 1.22^{hi}	7.72 ± 1.21^{j}	7.84 ± 1.21^{g}	5.00 ± 0.50^{e}
8	6.16 ± 2.29^{f}	5.82 ± 2.16^{h}	6.08 ± 2.10^{e}	8.52 ± 0.68^{b}
9	8.06 ± 0.89^{i}	8.06 ± 0.79^{j}	8.00 ± 1.31^{g}	8.28 ± 0.66^{b}
10	8.04 ± 0.99^{i}	8.18 ± 0.90^{j}	8.20 ± 0.97^{g}	6.20 ± 0.62^{d}
11	1.48 ± 0.74^{a}	1.54 ± 0.79^{a}	1.62 ± 1.12^{a}	7.48 ± 0.67^{c}
12	5.40 ± 2.18^{e}	5.24 ± 1.97^{b}	5.14 ± 2.02^{d}	8.44 ± 0.68^{b}
13	4.56 ± 1.92^{d}	4.08 ± 1.68^{f}	4.14 ± 1.92^{c}	2.18 ± 0.26^{hi}
14	8.10 ± 0.93^{i}	8.18 ± 0.87^{j}	8.26 ± 0.88^{g}	2.32 ± 0.28^{hi}
15	2.08 ± 1.26^{b}	2.68 ± 1.39^{bc}	5.08 ± 2.25^{d}	4.70 ± 0.52^{g}
16	4.50 ± 1.76^{d}	3.92 ± 1.87^{ef}	3.84 ± 1.63^{c}	2.42 ± 0.29^{i}
17	2.28 ± 0.93^{bc}	3.38 ± 1.56^{de}	2.82 ± 1.30^{b}	9.52 ± 0.76^{a}

Mean values with different superscripts across the column are significantly different ($p < 0.05$).

Conclusions

This study showed that the processing variables (boiling temperature, coagulation time and coagulant volume) in the production of soft unripened cheese affected its quality attribute. The increase in the boiling temperature and coagulation time at a constant coagulant volume increased the total ash content of soft unripened cheese. The increase in boiling temperature and coagulation time at a constant coagulant volume decreased the yield, crude protein and colour attributes. Increase in boiling temperature and volume of coagulant at constant coagulation time decreased the moisture content, fat and pH of soft unripened cheese. The increase in coagulation time and coagulant volume decreased the textural attributes of soft unripened cheese. The samples were less preferred when the boiling temperature and coagulation time increased. The most acceptable soft unripened cheese can be processed at processing condition of 80 ºC boiling temperature, 25 min coagulation time and 4 mL coagulant volume. Soft unripened cheese production should be promoted on an industrial scale, as it offers a valuable source of energy and high-quality protein, especially in areas facing food insecurity. However, to enhance the safety and quality of soft unripened cheese, future studies should be carried out on long-term shelf life evaluation and microbial stability assessment.

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