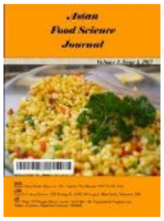

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Yield, Quality and Shelf-life Responses of Three Varieties of Soybeans to Three Processing Temperatures Using the Vitagoat System of Soymilk Production

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Authors' contributions

This work was carried out in collaboration between all authors. Author EA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors BKM and PYA managed the analyses of the study. Author PKT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Three improved varieties of soybean, Anidaso, Nangbaar and Quarshie were used in the study to determine the effect of variation and processing temperature on the yield, quality and shelf-life of soymilk produced by the VitaGoat processing system. Two kilograms of each of the varieties were processed into soymilk at three temperatures of 110°C, 115°C and 120°C. The yield of each variety at the various temperature levels was measured by the total volume of the soymilk produced. Three samples of the soymilk from each variety were randomly selected for proximate analysis. Five samples were also randomly selected, kept at room temperature and monitored daily for three weeks to determine their shelf-life based on spoilage by coagulation. Nangbaar variety processed at a temperature of 110°C recorded the significantly highest soymilk yield and the least was recorded by Quarshie variety treated at a temperature of 120°C. Soymilk produced at 110°C

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was significantly ($p<0.01$) highest in protein content than at 115°C or 120°C. The combined effect of Anidaso and 110°C was significantly ($p<0.01$) highest in protein content than that of the other combinations. The soybean varieties did not significantly ($p<0.01$) influence the shelf-life of soymilk during the study. Soymilk produced at 120°C had significantly ($p<0.01$) longer in shelf-life than that of 110°C and 115°C. Quarshie at 120°C had significantly ($p<0.01$) longest in shelf-life than that of the other interactions. It was concluded that Anidaso at 110°C was rated the best among the varieties and processing temperature for producing high protein content soymilk.

Keywords: Malnutrition; denaturation; proximate; evaporation and utilization.

1. INTRODUCTION

Soybean (*Glycine max L.*) is a grain legume crop native of Eastern Asia and several Pacific Islands. Its spread from the native land of origin has been due mainly to its predominant use as a food crop for human nutrition, a source of protein for animal feed, medicinal plant, and lately as industrial crop [1]. The leading producers of the crop are the United States of America (35%), Brazil (27%), Argentina (9%), China (6%), India (4%), Paraguay (3%) and Canada (3%) [2]. These countries are also large exporters [3]. Soybean is a relatively new crop in Ghana. It was initially introduced into the country in 1909 for export and animal feed but failed due to poor understanding of its cultivation and utilization. At maturity, soybean contains 38% protein, 30% carbohydrate, 18% oil, 14% moisture and varying levels of vitamins and minerals, including calcium, folic acid, and iron [4]. Nutritionally, it is an excellent source of protein. Hence the seed is considered the richest plant food consumed regarding food value [5]. Medically, soybean is helpful for brain development because it contains 3% lecithine amino acid [6]. Agronomically, it enriches the soil by fixing atmospheric nitrogen in symbiosis with bacteria for its own use with benefits to subsequent crops [7]. Industrially, soybean is useful as lubricants, emulsifiers and plasticizers [8].

The demand for soybean has increased after initial production of about 1,000 MT in 1990 to an estimated production of about 19,000 MT in 2012 [9] in Ghana. Some institutions like, Food Research Institute, Department of Family and Consumer Sciences, University of Ghana and the Women in Agricultural Development Directorate of the MOFA have intensified since 1995 their effort in promoting the use of soy in the country and has undertaken an extensive recipe development in Ghana. Several recipes have since been developed [10]. Soybean is known to be very important in our diets but how processing temperature affects the yield, the quality and even the shelf-life of different varieties of soybean when processed into soymilk needs to be identified [11]. The "VitaGoat" is a post-harvest preparing system that can be utilized to make quality food products from oats, grains, nuts, vegetables and fruits, empowering households to build food security, enhance wellbeing and make small-scale industries [12]. VitaGoats can give protein-rich nourishment to individuals in emerging nations where lactose-intolerance is regular or where conventional dairy items are inaccessible or expensive. Through subsidy given by the Silk White Wave Foods, the World Soy Foundation (WSF) had the capacity to buy, transport and install a VitaGoat Machine in western Ghana. As a feature of its philanthropic administrations, ADRA (Ghana) is likewise working together with WSF (World Initiative for Soy in Human Health, WISHH) to undertake VitaGoat project to deal with malnutrition problems in Ghana using soy intervention. A pilot project has been set up at Mafihuta and AMO Yaokope in the North Tongu and Dangme Districts in Ghana respectively, and also Techiman municipality, working with Valley View University, Techiman to reach basic schools in the area [13]. VitaGoat processing system makes use of temperature and pressure in the preparation of soymilk. Heat-based preparations can enhance the timeframe of realistic usability and wellbeing of a food item; it can likewise diminish the nourishing potential of foods and can produce off-flavours. For instance, warm treatment of soymilk can advance undesirable cooked flavours that can diminish utilisation of soymilk [14]. The project was designed to determine the effect of three soybean varieties and processing temperature on the yield, quality and shelf-life of soymilk from the VitaGoat processing system.

2. MATERIALS AND METHODS

2.1 Place of Production

The soymilk processing was carried out at Awurade Akwan Soymilk Factory, Agona in the Sekyere South district of Ashanti. The processing facility, the VitaGoat processing system was established by Professor J.K Osei, formerly of the University of Ghana, Legon and the past rector of the Valley View University, Techiman Campus. The processing system was established in collaboration with the Malnutrition Matters to produce soymilk on daily basis for the local people to improve their general health in the area. The facility has been carefully made to meet the standard of the Malnutrition Matters [15]. The standard seeks to ensure production of contamination- free soymilk.

2.2 Experimental Design

The laboratory experiment was set-up in 3x3 factorial arrangement in a Completely Randomized Design (CRD) replicated three times. The first factor was the variety with three levels; Anidaso, Nangbaar and Quarshie. The second factor was the processing temperature with three levels; 110°C, 115°C and 120°C.

2.3 Soymilk Processing Procedure

The VitaGoat soymilk was produced as follows:

1. The 2 kg of each of the varieties were soaked in clean water for eight hours. This made the seeds imbibe water to become soft enough to be milled by the electric grinder at the processing center.
2. For each batch of 2 kg, twelve liters of clean water were added to the milled seeds and placed in the pressure cooker which was then covered tightly.
3. Hot steam at a standard pressure of 40-80 psi from the boiler was introduced into the pressure cooker till the temperature rose to the temperatures needed for the project i.e. 110°C, 115°C and 120°C for each batch of production.
4. The cooking at each temperature; 110°C, 115°C and 120°C, were monitored for 15 minutes.
5. The cooked soymilk at each processing temperature was slowly discharged to the press lined with a filter
6. The filtered soymilk was collected in stainless steel containers
7. The cooked soymilk was bottled hot from the stainless steel containers for each of the temperature regimes. 300ml sterilized bottles were used for collecting the soymilk.

Collection of Samples and experimental procedure

At each processing temperature of the same variety, a number of sterilized bottles were used to collect the soymilk samples and labeled. The colour of the bottle tops were used in the labeling of the samples as follows:

Table 1. Labeling of samples

Variety	Processing temperature		
	110°C	115°C	120°C
Anidaso	Red	Yellow	White
Nangbar	Silver	Blue	Green
Quarshie	Pink	Gold	Red/White

300 ml sterilized bottles were used to collect soymilk samples at 110°C, 115°C and 120°C for each variety. This helped in recording the whole quantity of milk produced by each of the varieties at each of the temperature levels. The total number of bottles of each of the samples for the three varieties was used to compute the yield (kg) of each variety at the temperature levels. Five replicates of each of the samples were also kept for three weeks and were monitored on daily basis to determine their shelf- life. Three replicates of the samples of each of the temperature regimes were randomly selected for proximate analysis. The laboratory analysis was carried out at the Soil Science Laboratory of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

2.4 Parameters Studied

Data collected in the study were;

2.4.1 Yield

A number of 300 ml sterilized bottles were used to collect the soymilk produced and the total number of bottles of each of the samples for the three varieties was used to compute the yield (kg) of each variety at the temperature levels as stated in the VitaGoat production manual [15].

2.5 Determination of Proximate Composition

The soymilk samples were evaporated at 105°C for 48 hours and the dry matter used for the proximate analysis.

2.5.1 Moisture determination

This was determined using the Dry Method (Indirect Distillation) according to the procedure by [16]. Calculations were made using the formula;

(A + B) - A = B
(A + B) - (A + C) = B – C = D
% Moisture = D/B × 100

Where A = crucible weight, B = sample weight, C = dry sample weight, D = moisture weight.

2.5.2 Ash determination

This was done following the procedure by [16]. Percentage ash was calculated using the formula

(A + B) – A = B
(A + C) – A = C
% Ash = C/B × 100

where A = crucible weight, B = sample weight, C = ash weight.

2.5.3 Fat determination

This was done following the procedure by [16]. Percentage fat was calculated using the formula

(A + B) – A= B
% ether extract = B/C x 100

Where A = flask weight, B = ether extract weight, C = sample weight

2.5.4 Carbohydrate (CHO) determination

The total carbohydrate in the samples was determined by adding the percentages of all the other proximate compositions already determined and subtracting the calculated sum from 100.

CHO = (100-% moisture +% crude protein + %crude fat+ % crude fibre + % ash).

2.6 Data Analysis

The data collected was subjected to statistical analysis using analysis of variance (ANOVA). Statistical software used was the 9.0 version of Statistix. Testing for the differences between the means was at 1% level ($p < 0.01$).

3. RESULTS

3.1 Effect of Variety and Processing Temperature on Yield of Soymilk

There was a significant variety and processing temperature interaction ($P<0.01$) on the yield of soymilk (Table 2). Nangbaar variety processed at a temperature of 110°C recorded the significantly highest soymilk yield and the least was recorded by Quarshie variety processed at a temperature of 120°C.

Regarding processing temperature, soymilk processed at 110°C temperature resulted in the highest mean yield and 120°C recorded the least.

Across the varieties, the highest and lowest mean yield of soymilk were recorded by Nangbaar and Quarshie respectively.

3.2 Varietal Effect on Proximate Composition

Results of the proximate composition of soymilk revealed that, the highest and lowest significant fat contents were recorded by Nangbar and Anidaso varieties respectively (Table 3). Significantly highest protein and ash contents were recorded by Anidaso, Naagbaar recorded the least protein content which was similar to Quarshie variety. Quarshie variety recorded the significantly lowest ash content. Moreover, the varieties significantly influenced the moisture content of soymilk whereby the highest and lowest values were recorded by Nangbaar and Anidaso respectively. With respect to carbohydrate, Quarshie variety significantly produced the highest and the least was recorded by Anidaso.

Table 2. Effect of variety and processing temperature on yield of soymilk

Variety	Processing Temperature			Mean
	110°C	115°C	120°C	
Anidaso	16.07bc	16.07cde	15.43efg	16.03b
Nangbar	17.43a	17.00ab	16.27cd	16.9a
Quarshie	15.60def	15.13	14.77g	15.18c
Mean	16.58 a	16.07 b	15.499c	

Lsd (0.01) Variety=0.394, Temperature= 0.394 Var X Temp=0.683
**Means with the same letters within a column are not significantly different at 1% using L.S.D.*

Table 3. Effect of variety on proximate composition

Variety	Proximate composition (%)				Carbohydrate
	Fat	Protein	Ash	Moisture	
Anidaso	1.22c	33.42a	5.06a	4.33c	56.24c
Nangbar	3.17a	29.75b	3.03b	5.85a	58.07b
Quarshie	1.58b	30.15b	1.70c	4.57b	62.23a
lsd (0.01)	0.12	0.44	0.28	0.61	0.96

**Means with the same letters within a column are not significantly different at 1% using L.S.D.*

Table 4. Effect of processing temperature on proximate composition

Temperature	Proximate composition (%)				Carbohydrate
	Fat	Protein	Ash	Moisture	
110°C	1.83b	34.54a	3.00b	4.55c	56.11c
115°C	1.82b	30.08b	5.20a	5.20a	58.94b
120°C	2.32a	28.70c	3.00b	5.01ab	61.49a
L.s.d (0.01)	0.12	0.44	0.28	0.61	0.96

**Means with the same letters within a column are not significantly different at 1% using L.S.D.*

There were significant differences between processing temperatures on the proximate composition of soymilk during the study. While the significantly highest fat content was recorded at 120°C, the least fat content was recorded at 115°C which was similar to fat content produced at 110°C. With respect to protein, the significantly highest soymilk protein value was recorded by the processing temperature of 110°C, while the least protein content was recorded at the processing temperature of 120°C. There were significant differences between the processing temperature for ash content where significantly highest ash was recorded at 115°C processing temperature while the least was recorded at 110°C and 120°C temperatures. The results also indicated that, soymilk processed at 115°C was significantly greater ($p<0.01$) in moisture than the processing temperature of 110°C, however, soymilk processed at 110°C produced significantly lowest moisture. In the case of carbohydrate, the highest and least values were produced at the processing temperatures of 120°C and 115°C respectively.

3.3 Interaction Effect of Variety and Processing Temperature on proximate composition

There was a significant interaction between variety and processing temperature on proximate composition of soymilk (Table 5). For fat content the significantly highest content was recorded by Nangbaar variety processed at the temperature of 115°C and the least was recorded by Anidaso processed at 115°C. With respect to protein, Anidaso variety processed at 110°C recorded the significantly highest protein and the least was recorded byNaagbaar which was processed at 120°C. Regarding ash content, the highest ash content was recorded by Anidaso processed at a temperature of 115°C and the least was recorded by Quarshie processed at 110°C temperature. The results also showed that significantly highest moisture content was recorded by Nangbaar variety processed at 115°C while Anidaso processed at 110°C produced the least moisture. Furthermore, it was observed that Quarshie processed at 115°C recorded the highest carbohydrate content which was similar to Quarshie processed at 120°C. The least carbohydrate was produced by Anidaso variety processed at 110°C which was also similar to Nangbaar processed at 110°C.

3.4 Effect of Variety and Processing Temperature on Shelf-life of Soymilk

There were variety and processing temperature interaction (Table 6). Significantly highest shelf – life was recorded by Anidaso at 110°C, which was similar to all the varieties at 110°C and 115°C. However, significantly shortest shelf-life was obtained by Quarshie at 120°C and longest shelf-life by Anidaso at 120°C

4. DISCUSSION

The varieties of soybean such as Anidaso, Nangbaar and Quarshie have little effects on the yield of soymilk. The results of the present study revealed that variety and temperature

Table 5. Interaction effect of Variety and processing temperature on proximate composition

Variety*temperature	Proximate composition				Carbohydrate
	Fat	Protein	Ash	Moisture	
Anidaso*110°C	0.91g	37.24a	4.07c	3.89c	53.91e
Nangbaar*110°C	3.16b	32.72c	3.49d	5.42ab	55.27e
Quarshie*110°C	1.42f	33.67b	1.44f	4.34c	59.15cd
Anidaso*115°C	0.53h	33.52b	6.54a	4.55bc	54.87e
Nangbaar*115°C	3.47a	29.24d	3.13d	6.15a	57.53d
Quarshie*115°C	1.47f	27.47e	1.74f	4.90bc	64.43a
Anidaso*120°C	2.23d	29.5d	4.59b	4.57bc	59.94bc
Nangbaar*120°C	2.88c	27.3e	2.47e	5.97a	61.42b
Quarshie*120°C	1.86e	29.31d	1.91f	4.48bc	63.10a
Lsd (0.01	0.21	0.76	0.49	1.06	1.67

**Means with the same letters within a column are not significantly different at 1% using L.S.D.*

Table 6. Effect of Variety and processing temperature on Shelf-life of Soymilk (days)

Variety	Processing Temperature			Mean
	110°C	115°C	120°C	
Anidaso	5.00a	4.67a	2.33b	4.00a
Nangbar	4.67a	4.33a	1.67bc	3.56a
Quarshie	5.00a	4.67a	1.00c	3.56a
mean	4.89 a	4.56a	1.67a	

Lsd (0.01) Variety=0.76, Temperature= 0.76 Var X Temp=1.31

**Means with the same letters within a column are not significantly different at 1% using L.S.D.*

significantly influenced the yield of soymilk. Nangbaar variety of soybean yielded the highest significant amount of soymilk. This may be partly due to different genotypes of the soybeans coupled with the different temperatures. Similar revelations was reported by Gesinde et al. who identified significant differences in the effect of variety on the yield of soymilk [11]. The results also showed that, processing temperature of 110°C produced the highest yield of soymilk relatively to the processing temperature of 115°C. This could be attributed to the differences in the soybean varieties and the varying temperature levels. The results of the current study contradicts that of Bhardwaj et al., who reported that soybean genotype significantly affected the soymilk parameters except the yield [17]. The authors also explained that soymilk yield is not correlated with seed characteristics and processing temperature. Within the temperature range used in the experiment, soymilk yield was affected differently. The lowest temperature gave the highest yield of soymilk. This could be due to the rate of evaporation which increases with high temperature [18], resulting in the decrease in yield at high processing temperature. Regarding the effect of a combination of variety of soybean and temperature, it was realized that Nangbaar variety which gave the highest yield of soymilk produced even higher amount of soymilk when combined with the lowest processing temperature. This may also partly be due to the high rate of evaporation at the higher temperature [18]. The present work revealed that, Nangbaar recorded highest fat content. This could be attributed to the different genetic composition of the varieties of soybean used for the research as well as the production environment that might have influenced the differences in fat content.

Research available indicate that various varieties of soybean differently influence proximate composition. The present study is not different from the research carried out by Khatib and Aramount who identified variety as one of the factors affecting soymilk quality [19]. The highest protein content recorded by Anidaso may be attributed to the varietal difference of the soybean. Murphy et al., reported that the ratio of proteins varies among varieties and can affect the quality of soymilk [20]. Zhang et al., further reported that soybeans are widely known as a high quality, cholesterol free, low-cost protein source and are principally vegetable proteins globally [21]. Anidaso recorded the highest ash content, probably due to more mineral being extracted from Anidaso soybean variety compared to less mineral that might have been extracted from the others [22]. The moisture content recorded in the study was significantly between 5.85% to 4.57% by Nangbaar and Quarshie respectively. The low moisture contents recorded might be attributed to the fact that the soybean varieties were obtained at a low moisture content for the study. However the study by Gesinde et al. recorded high average moisture content (91.24) which are different from the average moisture content (4.92) of the present study [11]. Quarshie recorded the highest composition of carbohydrate probably due to varietal differences among the cultivars used in the present study. This is different from the findings by Gesinde et al. who reported a very low carbohydrate content (2.26%) in their research work [11]. Heat is one of the modifying soymilk extraction methods [23]. Egbo, reported that thermal processing has an effect on the quality of soymilk with particular reference to proximate composition [24]. The effects of the various temperature levels on fat composition revealed that, the highest fat content was obtained at 120°C which could be due to the different heat levels melting more fat as well as different soybean varieties used in the study and that soy fat which is of high quality and cholesterol-free is higher when soymilk is processed at higher temperature. The results obtained in the current study also revealed that, temperature was inversely proportional to protein content. The lowest temperature level had the highest amount of protein composition which confirms the research work done by Sara who opined that the structure of proteins changes with the increasing heat [25]. So protein is denatured at high temperature, reducing the quality of soymilk.

Fresh soymilk has a very short shelf-life which limits consumption to areas close to the production site [14]. The assessment of spoilage of soymilk for the various varieties of soybean showed that, Anidaso recorded a shorter shelf-life compared to Nangbaar and Quarshie. This may be due to the differences in the pH content of the various varieties as it was suggested by Adebayo-Tayo et al. [26]. Regarding how processing temperature affects the shelf-life of the soymilk, the highest processing temperature of 120°C increased the shelf-life of the VitaGoat-processed soymilk. This follows that higher processing temperature has the potential of destroying micro-organisms that cause spoilage [14]. Assessing the combined effect of variety of soybean and temperature levels, a combination of Quarshie and Nangbaar at 120°C gave the longest shelf-life of a soymilk. Kwok et al. reported that thermal processing can improve the microbial safety and extend the shelf-life of soymilk as it inactivates many spoilage organisms. Though using a temperature level of 120°C gave a better shelf-life, combining this processing temperature with Quarshie will yield a better shelf-life of the soymilk and hence reduce its spoilage [14].

5. CONCLUSION

The study revealed that the best variety for producing high yielding soymilk was the Nangbaar which yielded 16.9 L of soymilk as against 16.07 L and 15.17 L yielded by Anidaso and Quarshie respectively. The processing temperature of 110°C yielded the largest quantity of soymilk (16.58L) as compared to 16 L and 15 L produced at the temperatures 115°C and 120°C respectively. The interaction of Anidaso and 110°C gave the highest yield of soymilk (17.43 L) than the rest of the interaction between the varieties and the temperatures. Nangbaar had the highest contents of fat (3.17%) and moisture (4.33%), Anidaso also had the highest protein content (33.42%) and ash (5.06%) while Quarshie had the highest content of carbohydrate (62.23%). The processing temperature of 120°C gave the highest content of fat (2.32%) and carbohydrate content (61.49%), 110°C gave the highest content of protein (34.54%) while 115°C gave the highest ash content (3.80%) and moisture content (5.20%). The interaction of Nangbaar by 115°C had the highest fat content (3.47%) and moisture (6.15%), Anidaso at 110°C had the highest protein content (37.24%), Anidaso at 115°C had the highest content of ash (6.54%), Nangbaar and 115°C had the highest moisture (6.15%) while Quarshie by 115°C had the highest carbohydrate content (64.43%). The shelf-life of Nangbaar and Quarshie were found to be longer as a small percentage (3.56%) spoiled after three weeks as compared to Anidaso which had 4.00% spoilt. The processing temperature of 120°C gave the longest shelf-life of soymilk as the least percentage (1.6%) spoiled. Meanwhile, Quarshie by 120°C interactions had the longest shelf-life of soymilk since the interaction gave the least percentage (1.00%) of the samples of soymilk kept for three weeks spoilt as compared to the rest of the interactions between the varieties and the temperatures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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