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Quality Retention and Inhibition of Thermophiles in Milk Using a Novel 3-Stage Recyclable Batch Pasteurizer

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Abstract: Milk quality decline and proliferation of microorganism can be prevented by heat-treatment. This however can denature the nutrients under excessive processing condition. There is therefore a need to selectively apply and evaluate this technology for milk pasteurization. In this research, the performance of a novel 3-stage recyclable batch milk pasteurizer operating at varying temperature (63– 71 °C), stirring speed (15 – 25 rpm) and holding time (15 sec – 30 min) was determined. The equipment has a hot water storage, pasteurization, and cooling tanks, which maintain the temperature of the pasteurized milk sample to 3–5ºC. The nutritional quality and the thermophile loads, including Streptococcus, Clostridium, Micrococcus, and Lactobacillus in the sample were determined as performance indices. The results show no significant trace of the thermophiles ($p < 0.05$) and a high value of the nutritional composition at 63°C, 25 rpm stirring speed and 15 min holding time. The quality of the product decreased progressively with an increase ($p < 0.05$) in the temperature and speed for all holding time. Thus, the equipment can be used for milk pasteurization with a reduced nutrient denaturation and thermophiles proliferation.
Keywords: Thermophilic bacteria; Nutritional quality; Pasteurizer; Milk.

1. Introduction

Pasteurization is a technological procedure in which milk is pretreated with a relatively mild heat to kill pathogenic microorganisms and extend its shelf-life [1]. It is also done to inactivate enzymes that may cause the spoilage of the product or prevent the proliferation of bacteria and other pathogens [2–4]. The pasteurized milk has several advantages over its none pasteurize counterpart because of the health benefit presented by the former. The risk of disease transmission through milk consumption can be reduce to almost two-third if the product is pasteurized prior to further processing. Traditionally, milk is pasteurized by scalding and straining of cream at low temperature of around 60ºC and slow heating for just 20 minutes to increase the keeping quality of the resulting product [5,6].

The pasteurization of the milk can be done in two ways [6]. It can be done before packaging into a container and after packaging. The packaging of raw milk in glass container usually requires immersion in hot water bath to prevent the incidence of thermal shock before pasteurization [7]. Other equipment like the plate, scrap surface, shell and tube heat exchangers have been designed to pasteurize milk by allowing the product to flow through a separating or bounded media [8], which receives the heat to kill the microorganisms in the product.

Even though this technology is very effective in killing pathogens, inactivating enzymes, and extending the shelf-life of milk, there are reports in the literature discouraging its long-term application. For example, [9] evaluated a system for pasteurizing calf milk and reported a possibility of nutrient denaturing even when exposed to low temperatures. In fact, Nada et al. [10], Jaynes [11], Giribaldi et al.[12] and Elmagli et al. [13] also reported similar findings, thus making this technology less acceptable to the food industry nowadays. There is a need therefore to selectively apply equipment for milk pasteurization. There is also a need to modify the pasteurization technology and provide a more acceptable approach that may not denature the nutrients in the milk during processing. As a rider to the work of Sunmonu and Sanusi [14], who recently invented and patented the design of a 3-stage milk pasteurizer, equipped with a storage, pasteurization, and cooling units, we report here the performance of the equipment as regard to its suitability for microbial growth inhibition as well as preventing quality decline in the milk. The goal is to promote the commercial application of this equipment by justifying its

potential to compete with similar technologies for milk pasteurization in the food industry. Thus, this research investigates the performance of the new equipment for application to minimize the growth of thermophilic bacteria, such as Streptococcus, Clostridium and Micrococcus, which are known to thrive at 53ºC, and to prevent nutrient denaturation in the milk during pasteurization.

2. Materials and methods

2.1 Description of the novel pasteurization equipment

A 3-stage recyclable batch pasteurizer was invented for raw milk pasteurization [14], as shown in Figure 1. The equipment consists of three units for hot water storages, pasteurization, and cooling. The hot water storage unit consist of two tanks and has a total capacity of 12.67 m^3. The inner tank is made of stainless steel while the outer tank is made of mild steel. A water heater, with 2 kW rating, was installed at the base of the inner tank and inserted into the outer tank to form a jacket. The pasteurizing unit, which has a volume of 7.85 m^3, was also made up of an inner stainless-steel tank for pasteurization and an outer covering made of the mild steel. The cooling unit, which has a capacity of 7.85 m^3, collects the hot milk and cool it to 4ºC with the help of a condenser installed at the base of an inner stainless-steel tank. A fibred glass lagging material was used in the interspaces between tanks to minimize heat loss or gain by convection. A stirrer was incorporated at the center of the pasteurization chamber, which was powered by a 0.5 HP electric motor, to ensure a uniform temperature distribution in the system. The pasteurizer also consists of three sieves placed at the entrance of the pasteurizing chamber (microfiltration of 0.8 µm diameter), another one placed at the exit of the pasteurizing chamber or inner (nanofiltration of 0.01 µm diameter) and the last one placed at the outlet of the cooling unit (nanofiltration of 0.01 µm diameter). This was done to reduce the microbial effect of bacteria and maintain nutritional values of the milk at each stage of filtration. A thermocouple was installed to regulate the temperature of the hot water storage, pasteurizing unit, and the milk chiller. The heater, coolant and the thermocouple were connected to the temperature controller through a probe of 6 mm stainless steel and the controller was connected to a power source. The water storage would enhance water recycling through the pump and minimize water wastage. A 20 mm aluminum pipe was connected to the hot water storage from where water is conveyed by steel pump into the pasteurizer tank and to the cooling system. Valves were incorporated at the entrance and exit of the cooling unit for easy collection of the pasteurized milk sample. All the electric components were housed inside a panel with a dimension of 340 × 140 mm; and a toggle switch was used for controlling the electrical appliance. The entire machine assembly was placed on a standing frame fabricated with the mild steel pipe and metal plate of 1.5mm thickness.

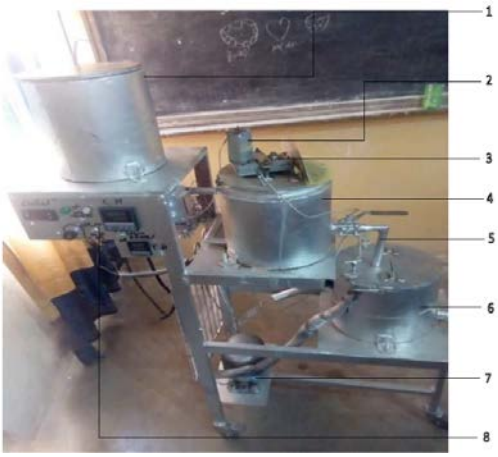

Figure 1. Invented 3-Stage Recycling Batch Pasteurizer for raw-milk (1-Hot water storage tank, 2- Water pump, 3- Stirrer, 4- Pasteurization tank, 5- 20 mm Aluminum pipe, 6- Cooling tank, 7- Frame, 8- Control panel)

2.2 Milk sample preparation

The milk used in this investigation was obtained from a white Fulani breed of cow. It was collected from a mature cow after carefully cleaning the udders in the mammary gland. The milking process was carried out in a room to avoid contaminations from the environment. The milk was manually tapped from the udder of the cow and collected in sterile container. The collected milk was covered and placed in a 50 litres container, which was surrounded by blocks of ice to maintain the surrounding temperature at 3- 5ºC before subsequent experiment. The milk samples were immediately transported to the University of Ilorin Central Research Laboratory for initial analysis of the nutritional composition and microbial counts.

2.3 Experimental procedure

The 3-stage recyclable batch pasteurizer was used to pasteurize the milk sample over varying temperature (63–71 °C), stirring speed (15 – 25 rpm) and holding time (15 sec – 30 min) conditions. The equipment was first cleaned with hot water to ensure safety and hygiene before pasteurization begins. The milk sample was thereafter introduced into the pasteurization tank, and water introduced in the hot water storage tank. The machine was started, by engaging the switched on the control panel, and the temperature of the water in the storage tank was set to 63ºC. The centrifugal water pump was also engaged to allow circulation of hot water between the pasteurizer tank and hot water storage. The milk was constantly stirred at a speed of 15, 20 and 25 rpm with the help of the stirrer in the pasteurization tank and hold for 15 sec, 15 min and 30 min, respectively. The milk was conveyed through a pipe to the cooling unit which maintains its temperature at 4ºC before it was collected in a laboratory container and sealed. This process was repeated for 66ºC and 71ºC hot water temperature to obtain a total of 27 pasteurized milk samples, as shown in Table 1. The samples were then taken to the laboratory for further analysis.

Table 1. Experimental layout

Stirring/HT Time (E)	**Pasteurizing temperature (T) / Stirring speed (S)**								
	T_1			T_2			T_3		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
E_1	$T_1S_1E_1$	$T_1S_2E_1$	$T_1S_3E_1$	$T_2S_1E_1$	$T_2S_2E_1$	$T_2S_3E_1$	T3S1E_1	$T_3S_2E_1$	$T_3S_3E_1$
E_2	$T_1S_1E_2$	$T_1S_2E_2$	$T_1S_3E_2$	$T_2S_1E_2$	$T_2S_2E_2$	$T_2S_3E_2$	T3S1E_2	$T_3S_2E_2$	$T_3S_3E_2$
E_3	$T_1S_1E_3$	$T_1S_2E_3$	$T_1S_3E_3$	$T_2S_1E_3$	$T_2S_2E_3$	$T_2S_3E_3$	T3S1E_3	$T_3S_2E_3$	$T_3S_3E_3$

* Stirring /Holding Time (E1=30 min, E2= 15 min, E3= 15 sec), Stirring Speed (S1= 15 rpm, S2= 20 rpm, S3= 25 rpm), and Pasteurizing Temperature (T1= 63ºC, T2= 66ºC, T3= 71ºC)

2.4 Determination of nutritional and microbial quality of pasteurized milk

The nutritional quality, such as moisture, ash, crude protein, crude fibre, carbohydrate, and lipids contents, of the pasteurized milk samples was determined using the standard procedure reported by Kon [15], Guetouache et al. [16], Fadeyibi et al.[17], and Sunmonu et al. [18]. The microbial growth level in the pasteurized samples were determined according to the procedure reported by Brodziak et al. [19] and Fadeyibi et al. [20] for total viable count, which includes the analysis for the presence of thermophilic bacteria such as Streptococcus, Clostridium, Micrococcus, and Lactobacillus. Initially, all the glassware were cleaned and sterilized in an oven at 160ºC for 1 h to avoid contamination of samples. This is followed by adding 7 g of a Nutrient Agar media into a 250 ml conical flask containing 100 ml of distilled water and stirred continuously until it dissolves. The sample was sterilized at 121ºC for 15 min and serially diluted. Pour plate method was used for cutting of bacterial by picking 0.1 ml of the milk sample and dropping it at different point on a Petridis using a pipet. The nutrient agar solution was then poured in excess and allowed to solidify by sealing with aluminum foil at 37ºC for 24 h [21]. The bacteria cultured were further classified for traces of the thermophiles using the method described by da Costa and Nobre [22], Scott et al. [23] and Burgess et al. [24]. Also, the fungi and the coliform counts in the sample were evaluated using the technique described by Banik et al. [21] in the laboratory manual of microbiology.

2.5 Experimental design and analysis of variance

A 3^3-factorial experiment in completely randomized design was used in this research work. The experimental factors were the pasteurizing temperature (T), stirring speed (S) and stirring time (E). The pasteurizing temperatures were 63, 66 and 71 °C. The stirring speed were 15, 20 and 25 rpm at stirring time of 15 sec, 15 min, and 30 min. Each treatment combination was replicated thrice, making a total of 27 test trials, and analyzed according to the procedure reported by Fadeyibi [25]. The Duncan's multiple Range test (NDMRT) was used to analyze the effect of the temperature, stirring speed and stirring/holding time variabilities on the microbial and nutritional compositions of the pasteurized milk sample at $p < 5\%$.

3. Results and discussion

3.1 Effect of processing condition on thermophile growth inhibition in the pasteurized milk

The effects of the temperature, stirrer speeds and holding time on the microbial loads of the raw and pasteurized milk are shown in Figures 2- 3. The two common methods used in batch pasteurization, namely Low Temperature Long Time (LTLT) and High Temperature Short Time (HTST) which milk is pasteurized at 63.5 ºC for 30 min and 71 ºC for 15 sec, respectively [26], were used to control the growth of the microorganisms. A constant value of 34% was obtained at holding time of 15 sec for the total viable counts in the pasteurized milk which is quite lower than the value obtained from the raw unpasteurized milk, as shown in Figure 2. Most of the microorganisms were destroyed by the heat of pasteurization, thus leaving only a small fraction in the product. This is in line with the findings of Nada [10], Nicoleta et al. [8] who reported a constant value of the total viable counts for different

brands of milk product after pasteurization. In another related investigation, Banik et al. [21] reported 32.69% of the total viable counts at 30 min holding time. Although, several reasons may lead to the occurrence of the bacterial contamination in the pasteurized milk sample such as defect in pasteurization machinery, contamination in the post pasteurized process due to poor processing and handling condition and substandard level of hygienic practice by working personnel [27], we believe that inadequate pasteurization time and temperature may be responsible for the proliferation of the microorganism faster than is expected. This is evident in the low amount (15.385%) of the total viable count obtained after the milk was pasteurized at 71ºC with the stirrer speeds of 15 rpm and held to cool for just 15 sec. In fact, increasing the stirring speed from 20 to 25 rpm has further reduced the viable count loads to 3.85% even at 63 ºC and 30 min holding time. This is in line with the finding of Grant et al. [28] who reported a pasteurization temperature of 72ºC as the standard temperature for controlling the proliferation of thermophiles in the milk.

There was a general decrease in the total coliform counts from 65.36% to 28.49% with an increase in the temperature and a decrease in the time of holding, as shown in Figure 3. Also, the stirrer peed play an important role in ensuring temperature distribution in the system, and as such influenced the amount of the coliform count in the milk. The stirrer speed of 25 rpm and a temperature of 63 ºC required just 15 sec to achieve effective pasteurization since only 24.58% was recorded. This may be due to the usage of plastics container which can be associated with the high TC in the milk samples and difficulty in cleaning the plastics material [27]. Lastly, pasteurization Holding Time of 15 min had no Total Coliform (TC). This is in line with the research finding of Kažimírová [29] and Panchal et al. [30] that total Coliform bacterial were supposed to be absent in pasteurized milk as they may not survive the pasteurization temperature.

The effect of the pasteurization temperature, stirrer speed and holding time on the total fungi count in the pasteurized milk is shown in Figure 4. High Total Fungi species (TFS) of 35.18% were observed at holding time of 15 seconds. The number of fungi per colony had more replicas at this holding time and this can be because of the occurrence of post pasteurization contamination in the milk, and other problem related to hygienic design of the equipment, cleaning, and sanitation procedures [31]. Also, it was conceivable that pipe dead ends may contain plank toxic bacteria communities or sessile bacteria without the extra cellular matrices that was typical of biofilms [3]. The average value of the total fungi species was less than 40%, and this was followed by a significantly less value of 7.41% at 15 sec, 15 min and 30 min holding times at $p < 0.05$ (Table 2). This is in line with the results from Alahmer and Alsaqoor [32] who reported that under condition of poor cooling with temperature greater than or less than 72ºC, many fungi species may not thrive higher pasteurization holding times.

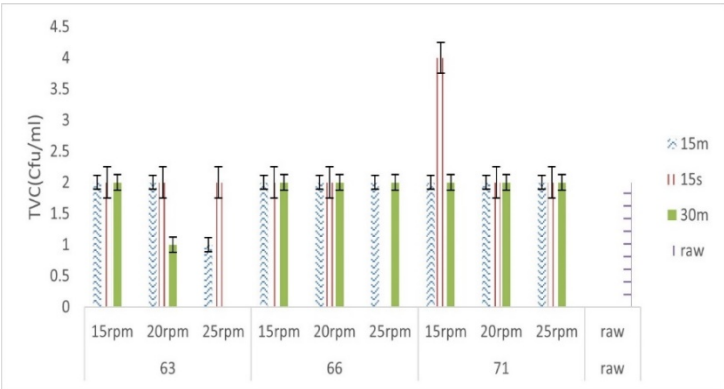

Figure 2. Effect of processing condition on total viable counts in raw and pasteurized milk

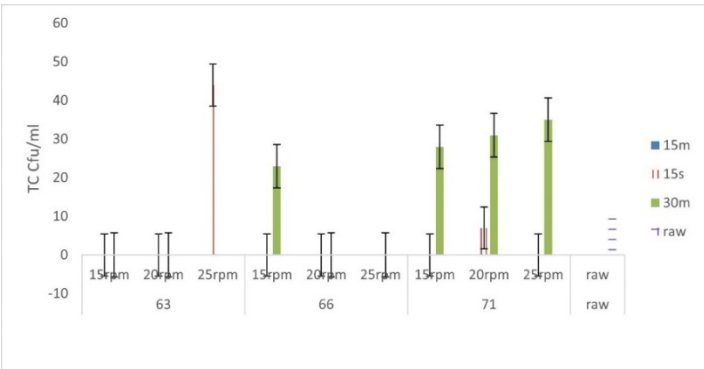

Figure 3. Effect of processing condition on total coliform in raw and pasteurized milk

Table 2. Average Summary Statistics of the Data Generated on Microbial Loads

Temp	Temperature (ºC)	Mean	Std. Error	Speed (Rpm)	Mean	Std. Error	Holding time	Mean	Std. Error
TVC1	Raw	62.25	20.15	Raw	62.25	20.15	Raw	62.25	20.15
	63ºC	57.22	7.97	15rpm	34.10	6.53	15secs	38.55	6.90
	66ºC	9.07	7.13	20rpm	39.22	7.08	15mins	35.09	7.08
	71ºC	51.46	6.54	25rpm	47.32	8.14	30 mins	46.16	7.56
DILUTION	Raw	550	441.26	Raw	550	441.26	Raw	550	441.26
	63ºC	662.50	174.42	15rpm	550	142.94	15secs	550	151.06
	66ºC	550	156.01	20rpm	600	155.04	15mins	600	155.04
	71ºC	550	142.94	25rpm	614.29	178.30	30mins	606.25	165.47
CFUML1	Raw	32100	21721.31	Raw	32100	21721.31	Raw	32100	21721.31
	63ºC	31625	8586.1	15rpm	14514.03	7036	15secs	17734.38	7435.78
	66ºC	3915.63	7679.65	20rpm	18088.9	7632.09	15mins	18650.14	7632.09
	71ºC	22241.8	6700.12	25rpm	27296.43	8776.74	30mins	21846.88	8145.71
TC1	Raw	6.50	4.09	Raw	6.50	4.09	Raw	6.50	4.09
	63ºC	3.32	1.62	15rpm	2.78	1.33	15secs	3.78	2.4
	66ºC	1.54	1.45	20rpm	2.39	1.44	15mins	0.14	1.44
	71ºC	5.59	1.33	25rpm	6.07	1.66	30mins	7.19	1.54
TFS	Raw	3	0	Raw	3	0	Raw	3	0
	63ºC	2.13	0	15rpm	2.33	0	15secs	2.13	0
	66ºC	1.75	0	20rpm	2	0	15mins	1.78	0
	71ºC	2	0	25rpm	1.44	0	30mins	2	0

* Temperature (**T_1**= 63 ℃, **T_2**=66 ℃, **T_3**=71℃) and Speed (**S_1**=15rpm , **S_2**= 20 rpm, **S_3**=25rpm), **E_1** = Pasteurization holding time 30minutes, **E_2**= Pasteurization holding time 15minutes, E_3= Pasteurization holding time 15seconds, **TVC** =Total Viable Counts(Total bacteria number),**TFS** =Total Fungi Spices, TC = Total Coliform (fecal coliform) , Cfu= Colony Forming Unit per ml, TFS = Total Fungal Species.

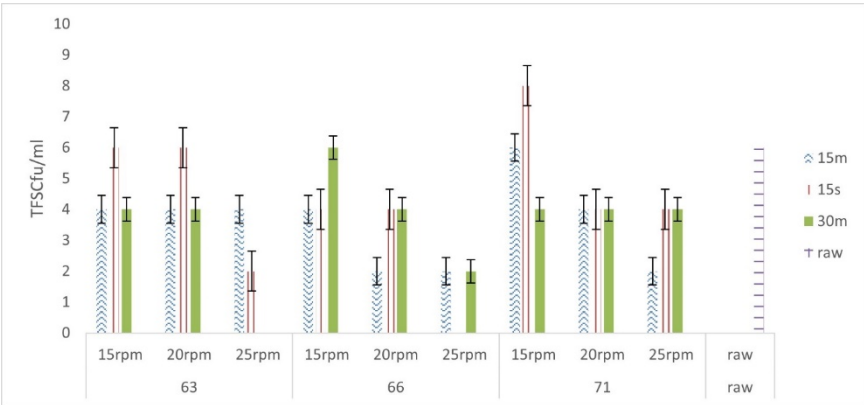

Figure 4. Effect of processing condition on total fungi load in raw and pasteurized milk

3.2 Effect of processing condition on nutritional quality of the pasteurized milk

The total nutritional compositions under different operating conditions of applied temperature, Stirrer speeds and operating holding time in the 3-stage recyclable batch pasteurizer is as presented in Figures 5- 10. The general observation on the mean value at different holding time at (15 sec, 15 min and 30 min) against the levels of applied temperature for all the three stirrer speeds used for the pasteurization is shown in Figure 5. The results show that irrespective of the applied temperature and stirrer speed, higher percentage of protein (37.37%) were observed at holding time of 15 sec. This was in line with the findings of Huppertz and Kelly [33] who reported that Protein varied within 3.7% to 4.2% depending on the breed, environment, and lactation period. However, milk pasteurized at holding time of 15 min and 30 min gave total protein of 25.28% and 33.77%, respectively. This corroborates the findings of Kelly et al. [34] who reported that protein was classified into 3 categories, and this determines the quantity and percentage. Although, when the milk was pasteurized at 63ºC with stirrer speed of 15 rpm at holding time of 15 sec percentage of protein was higher with values of 4.65% and protein percentage was lower with at 71°C stirrer speed of 15 rpm at 15 min which indicates 0.97% of the total protein fraction. The variation in protein values is also in line with the findings of Fakolade et al. [35] who reported that pasteurized milk of different samples varied in protein composition between 3.34% - 3.61%.

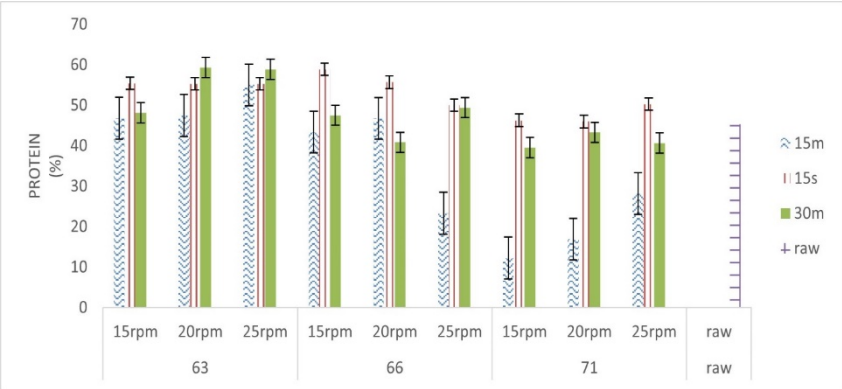

Figure 5. Effect of processing condition on protein fraction in raw and pasteurized milk

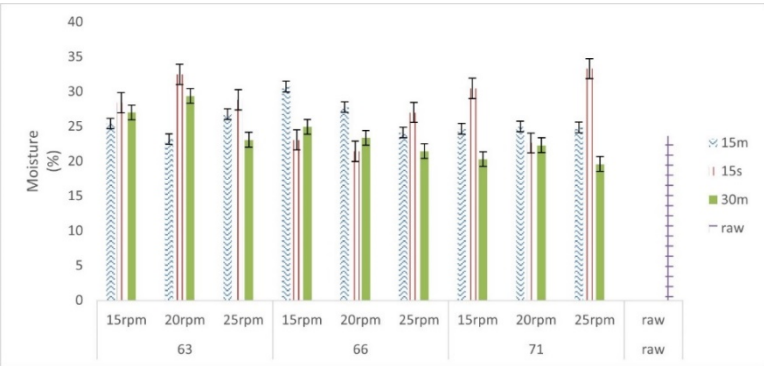

Figure 6. Effect of processing condition on moisture contents in raw and pasteurized milk

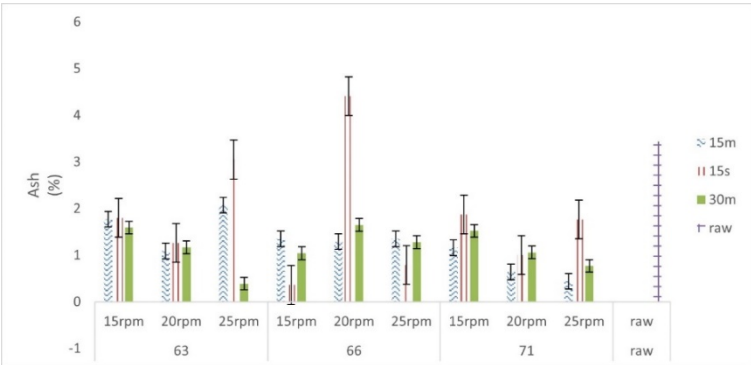

Figure 7. Effect of processing condition on ash content in raw and pasteurized milk

The moisture contents were higher at holding time of 15 sec with 34.36% of the total mean percentage, as shown in Figure 6. The results of the experiments agreed with the findings of Malik and Marouf [36] who reported slight decrease in the moisture content of milk samples pasteurized at 72 ˚C/15s and the higher moisture content was in the raw milk sample. This was followed by the milk pasteurized at holding time of 15 min and 30 min with values of 32.51% and 29.56% respectively. Also, milk pasteurized at 71ºC with stirrer speed of 25rpm at holding time of 15seconds and 30minutes shows that percentage of moisture content was higher and lower with values of (4.66%) and (2.74%) respectively. This is in line with observation from various researchers who reported that milk as a complex mixture that disperse in moisture and account for large percentage of nutritional composition of milk [33].

The effect of processing condition on the ash contents in the pasteurized milk is shown in Figure 7. The ash contents (39.42%) were higher at holding time of 15 sec compared with that obtained in the raw milk samples (8.31%). In a related investigation, Malik and Marouf [36] reported that the ash contents of the milk samples increase with an increase in the pasteurization temperature. Also, Woldemariam and Asres [37] observed that the ash content of the milk sample was significantly higher ($p<0.05$) than the control. Furthermore, this was followed by the milk pasteurized at holding time of 15 min which gave ash contents value of 26.97% and then holding time of 30 min with value of ash contents at 25.30%. However, when the milk was pasteurized at 66ºC with stirrer speed of 20 rpm and at holding time of 15 sec, percentage of ash contents was higher with value of 10.66% and

ash contents was lower (0.87%) at the same temperature (66ºC) with the stirrer speed of 15rpm at holding time of 15 seconds. The finding from the experiment is in line with Huppertz and Kelly [33], who observed earlier that milk from different breed had almost same ash contents.

The general observation of the mean values in Figure 8 shows the graphical illustrations of total percentage of lipid contents present in milk nutrient composition at different holding time against pasteurization temperatures for all the three selected stirrer speeds. The results revealed that higher percentage of lipid contents (38.97%) were observed at holding time of 15seconds. This corroborates the findings of Brodziak et al. [19] and Lu et al. [38] who reported minor effects on the nutritional value of milk fat and explained the small variations found in the fatty acid profiles of the milk analyzed. Pasteurized milk at holding time of 30 minutes and 15 minutes had total lipid contents of 30.13% and 27.34% respectively. The findings agree with Lu et al. [38] who reported that significant differences in the total lipid content between raw milk, pasteurized milk and yoghurt. The results of both milk types were within the requirements of minimum fat content of 3%. However, when the milk pasteurized at 71ºC with stirrer speed of 20rpm at holding time of 15seconds gave higher percentage of lipid contents with values of 6.26% and lower lipid contents with value of 0.39% was recorded at the same temperature of 71ºC with the stirrer speed of 25rpm and holding time of 15minutes. This is in line with the findings from Malik and Marouf [36] who reported that there were no significant variations in the chemical composition of the milk samples in all treatments.

The significant increase in percentage of fibre contents was 40.18% and this was observed at holding time of 30 min. The general observations from Figure 9 shows the total percentage of fibre contents present in milk nutrient composition of pasteurized and control samples at different holding time. The pasteurization holding time of 15seconds, and 15 minutes also shows high fibre contents in nutritional composition with values of 32.73% and 22.41% respectively. The results were contrary to findings of Obinna-Echem and Nkechi [39] in that pasteurization resulted in decreased crude fibre content of the fresh milk in wet season from 16.22% to 14.50% while an increase was observed for the milk in dry season from 13.77% to 14.37%. There was no significant difference in the fibre content of the pasteurized milk. Furthermore, samples pasteurized at 71ºC with stirrer speed of 25 rpm at holding time of 30 min had 16.41% of fibre contents when the variables were interacted, and it was lower at the same temperatures of 71ºC with the stirrer speed 15rpm at holding time of 15minutes with values of 0.41% of fibre contents. This is in line with the findings of Andersson and Öste [40] on the nutritional quality of pasteurized.

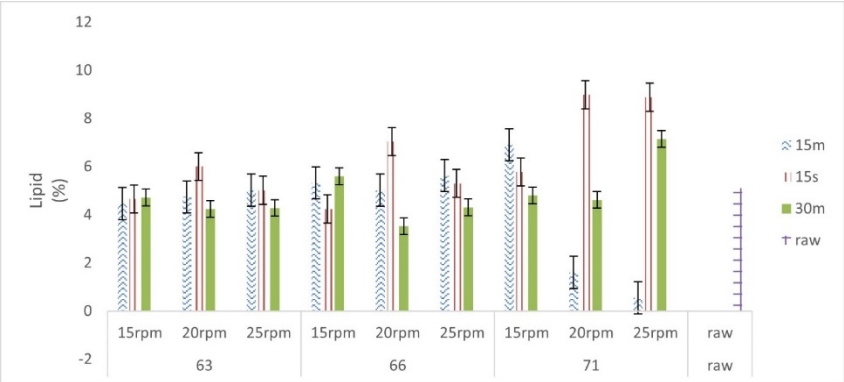

Figure 8. Effect of processing condition on lipid fraction in raw and pasteurized milk

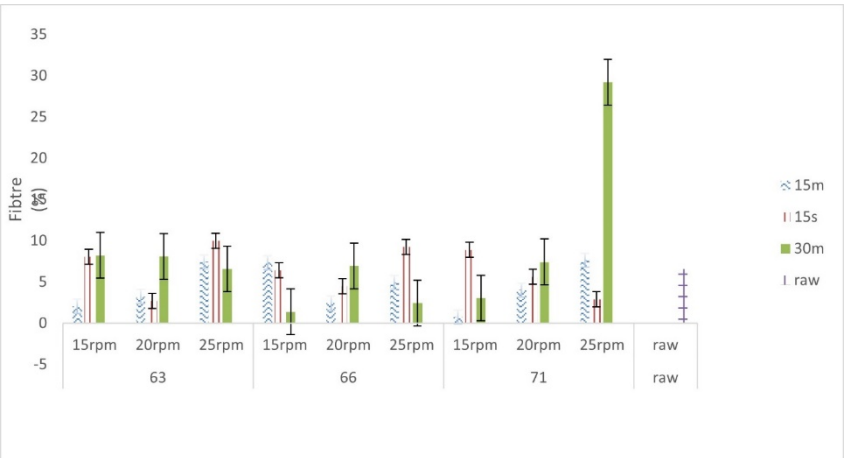

Figure 9. Effect of processing condition on fibre fraction in raw and pasteurized milk

Based on the mean value obtain from statistical analysis, the value of carbohydrates obtained from the pasteurized milk shows the percentage of carbohydrate contents present in milk nutritional composition. Figure 10 revealed that higher percentage of carbohydrate (35.6%) contents were observed at holding time of 15 min. The findings are in line with Woldemariam and Asres [37] observed that carbohydrate contents in samples were significantly different at $p < 0.05$ from the control. In addition, samples are significant at $p < 0.05$ in terms of their carbohydrate and solid-not-fat contents with each other, as shown in Table 3. However, pasteurization holding time of 30 minutes and 15 seconds also gave carbohydrate values of 31.76% and 29.09% respectively. Furthermore, milk samples pasteurized at temperature of 71ºC with stirrer speed of 15rpm and at holding time of 15minutes gave higher percentage of carbohydrate Content (4.7%). However, for the variable's interactions a carbohydrate value of 3% was recorded for samples pasteurized at temperature of 63ºC with the stirrer speed 25 rpm and at holding time of 15 sec. The research is in line with Malik and Marouf [36] the authors revealed that lactose was not found to be significantly different in all the milk samples. Therefore, the high total solids were found in the raw milk samples while the lower total solid were in the heat-treated samples.

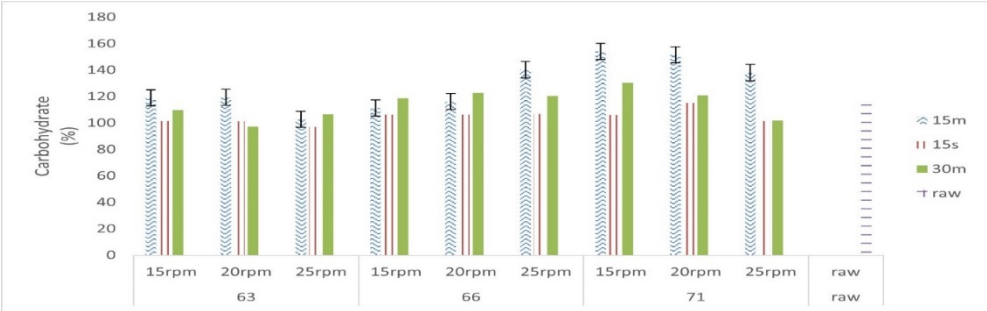

Figure 10. Effect of processing condition on carbohydrate content in raw and pasteurized milk

Table 3. Average Summary Statistics of the Data Generated

Nutrients	Temperature	Mean	Std. Error	Speed	Mean	Std. Error	Holding time	Mean	Std. Error
Protein	raw	22.65	0.182	Raw	22.65	0.182	Raw	22.65	0.182
	63	26.75	0.061	15rpm	22.11	0.061	15s	26.27	0.061
	66	23.09	0.061	20rpm	22.85	0.061	15m	17.78	0.061
	71	17.95	0.061	25rpm	22.83	0.061	30m	23.74	0.061
Moisture	raw	11.83	0.134	Raw	11.83	0.134	raw	11.83	0.134
	63	13.58	0.045	15rpm	13.05	0.045	15s	13.75	0.045
	66	12.43	0.045	20rpm	12.63	0.045	15m	12.91	0.045
	71	12.39	0.045	25rpm	12.72	0.045	30m	11.74	0.045
Ash	raw	1.72	0.02	Raw	1.72	0.02	raw	1.72	0.02
	63	0.79	0.007	15rpm	0.69	0.007	15s	0.91	0.007
	66	0.75	0.007	20rpm	0.75	0.007	15m	0.62	0.007
	71	0.57	0.007	25rpm	0.661	0.007	30m	0.58	0.007
Lipid	raw	2.55	0.026	Raw	2.55	0.026	raw	2.55	0.026
	63	2.40	0.009	15rpm	2.58	0.009	15s	3.11	0.009
	66	2.55	0.009	20rpm	2.54	0.009	15m	2.18	0.009
	71	2.74	0.009	25rpm	2.56	0.009	30m	2.40	0.009
Fibre	raw	3.27	0.037	Raw	3.27	0.037	raw	3.27	0.037
	63	3.13	0.012	15rpm	2.56	0.012	15s	3.24	0.012
	66	2.53	0.012	20rpm	2.50	0.012	15m	2.22	0.012
	71	3.86	0.012	25rpm	4.46	0.012	30m	4.07	0.012
Carbohydrate	raw	57.57	0.027	Raw	57.57	0.027	raw	57.57	0.027
	63	53.04	0.009	15rpm	58.73	0.009	15s	52.35	0.009
	66	58.29	0.009	20rpm	58.39	0.009	15m	64.04	0.009
	71	62.20	0.009	25rpm	56.42	0.009	30m	57.14	0.009

* Temperature (**T_1**= 63 ℃, **T_2**= 66 ℃, **T_3**= 71℃) and Speed (**S_1**=15 rpm, **S_2**= 20 rpm, **S_3**=25 rpm), **E_1** = Pasteurization holding time 30 min, **E_2=** Pasteurization holding time 15 min, E_3**=** Pasteurization holding time 15 sec, **TVC** =Total Viable Counts(Total bacteria number),**TFS** =Total Fungi Spices, TC = Total Coliform (fecal coliform) , Cfu= Colony Forming Unit per ml, TFS = Total Fungal Species.

4. Conclusions

A novel milk 3 stage recyclable pasteurizer was used to control the proliferation of thermophilic bacteria in milk while maintaining its nutritional qualities during pasteurization. The effect of the processing conditions of the equipment on the amount of the microorganisms and the nutritional values of the milk samples were determined. The results indicate only a slight difference ($p < 0.05$) in the amount of the nutrients between the raw and the pasteurized milk samples even at 71oC. This presents an advantage over other known pasteurization equipment since it did not denature the nutrients after heat treatment. The presence of the stirrer in the pasteurization tank, to cause an even temperature distribution, can be responsible for this unique behavior. The number of thermophilic bacteria was significantly lower at 63°C, 25 rpm stirring speed and 15 min holding time. This new equipment can therefore be used for milk pasteurization and can compete with other similar technologies.

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