Design of mini plant for soya milk production and pasteurization

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Abstract: A soya milk production and pasteurization plant was designed, fabricated and tested. The machine processed soaked soya milk to milk and also pasteurized it. Its major component parts include blending chamber, blending blade, furnace, boiler, temperature gauge and pasteurization chamber. The blending of soya beans, mixing the slurry and extracting the milk from the paste takes place in the milling chamber. The burning of biomass (briquette) takes place in the furnace and heating of water at the boiler. The pasteurization takes place in the pasteurizer. The machine capacity is 750 liters in 8 hours operational time per day. The results of testing of the machine revealed that blending efficiency and yield of milk were 88.16%, 98.52% respectively. The selected pasteurization temperature and time used were 84°C and 30 seconds. The machine was able to increase shelf life of raw soya milk from 24 (1 day) to 48 hours (2 day) when stored under room temperature and to 144 hours (6 day) when stored at temperature of 4°C (refrigerated).

Keywords: soya milk, production, plant and pasteurization

Citation: Gana, I. M., and A. Gbabo, 2017. Design of mini plant for soya milk production and pasteurization. Agricultural Engineering International: CIGR Journal, 19(4): 45–53.

1 Introduction

Soya milk is aqueous liquid obtained from extraction of milk from soya bean. It involves grinding of soaked soya beans with water to produce slurry, mixed of the slurry with water in order to separate the milk from chaff and sieving of the milk from the paste (Gbabo et al., 2012). The consumer's enlightenment on health effects of dairy milk consumption has contributed in acceptability and popularity of soya milk (Gbabo et al., 2012; Jinapong et al., 2008). Dairy milk consumption was reported by McGee (2004) to increase the risk of suffering from certain health problems such as cow milk allergy, which is not found in grains drink. According to Amusa et al. (2005) soya milk has numerous benefits such as social, economic, nutritional and medicinal for its numerous consumers. The affordability of this milk compared to other none alcoholic beverages such as soft drinks have also contributed in making it popular among the people. The major problems associate with locally processed soya milk is its contamination and short shelf life, also the production process is tedious and time consumption (Odu et al., 2012). The contamination of the milk could be as result of rusting of the processing equipment which is mostly made from mild steel material. Also the process involve different stages using different equipment which makes the production process tiresome, time consuming and the products are predisposed to contamination. In additional, there is possibility of contamination of beverages as result of wearing of component parts of milling plate with time of use (Gana, 2011).

The major disadvantage of food contamination is that it reduces the quality of the final product, thereby making it unhygienic. Many researchers have suggested possible causes of soya milk deterioration to include the pH of the milk which ranged between 7.0 to 7.5 and the activities of the various microorganisms contained in the milk, which may have been inherently present in the soya bean as reported by Adebayo-Tayo et al. (2009) or due to inadequate processing equipment and post processing contamination (Ikpeme-Emmanuel et al., 2009).

Generally, there is a lack of studies on the evaluation of new methods of processing and preservation of soya

Received date: 2017-02-18 **Accepted date:** 2017-03-18

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milk. Hence the design of the soya milk production and pasteurization plant would assist in increasing the shelf life of the milk.

2 Materials and methods

2.1 Machine description

Machine components

The mini plant was constructed using stainless steel materials and it is made of the following components:

i) Blending unit: This unit is made up of the following sub-component parts: outer casing, hopper, delivery tube, blending chamber, blending blade, shaft, pulley, V-belt and 2hp electric motor as shown in Figure 1-2.

ii) Hot water generating unit: This unit is made up of the following sub-component parts: furnace, boiler, temperature gauge, fiber glass as insulating material as shown in Figure 1-2.

iii) Pasteurization unit: This unit is made up of the following sub-component parts: stirrer, inner casing, water jacket, milk inlet and outlet valves, water inlet and draining valves, external casing as shown in Figures 1-3.

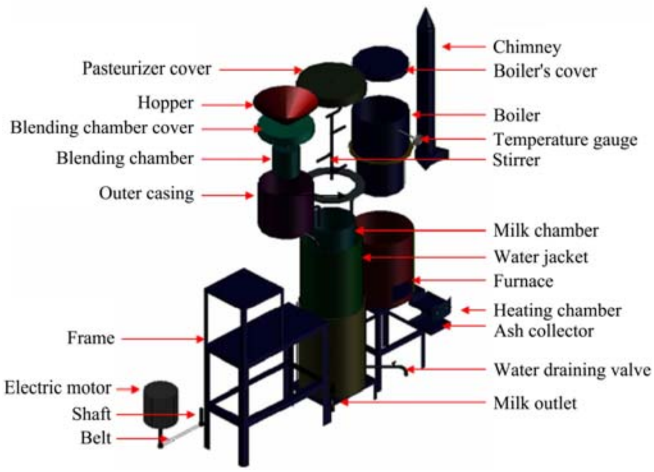

Figure 1 Exploded view of the machine

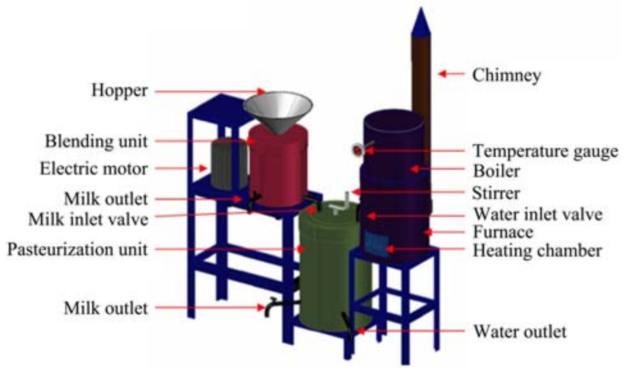

Figure 2 AutoCAD drawing of the mini plant

Figure 3 Front view of the machine

2.2 Mode of operations of the machine

The blending blade was fixed on the vertical shaft inside the blending chamber. The water tank was then mounted on the machine. The boiling tank was filled with water to the required level. Biomass material was fed into the furnace. Fire was set on the biomass materials. The grains were fed into the machine through the hopper. The power source was then switched on for blending operation. Water tank is opened for flow of water into the machine for washing of the milk. The milk outlet valve was opened for out flow of extracted milk to the pasteurization chamber. The temperature of the water was monitored through the temperature gauge. The boiler outlet valve was opened for the out flow of the hot water to the pasteurizer. The hot water was hold inside the pasteurizer for the required time. The pasteurizer outlet valve was open for outflow of the milk. The water jacket outlet valve was open for draining of the used water. The pasteurized milk is shown in Figure 4.

Figure 4 Sample of pasteurized milk

2.3 Design analysis of machine components

2.3.1 Determination of power requirement

The machine power requirement is a function of force up on materials inside the blending chamber such as weight of the blending blade, the shaft, and machine pulley. It is given by below Equations (1)-(5) as reported by Khurmi and Gupta (2005).

$$P = \frac{2 \times \pi \times N \times \tau}{60} \quad (1)$$

$$\tau = F \times r_d \quad (2)$$

$$F = M \times r_d \times \omega^2 \quad (3)$$

$$\omega = \frac{2 \times \pi \times N}{60} \quad (4)$$

$$M = (M_{SY} + M_B + M_S + M_P + M_{WT}) \quad (5)$$

where, P= power required by the machine (W); F = the total force (N); τ = the torque generated (N m), the M =total mass of the material contain in the blending chamber (kg); ω = angular angular speed of the blending blade (rpm); M_{SY} = mass of grain (kg); M_B = mass of blending blade (kg); M_S = mass of the shaft (kg); M_P = mass of the pulley (kg); M_{WT} = mass of the water (kg); π = constant; r_d = radius of the blade (m); N = revolution per minute (rpm).

2.3.2 Mass of soya beans to be processed at a time

The mass of soya beans to be processed is fundamental in computation of power needed by the machine. Considering the machine volumetric capacity to be 0.3632 m^3 (144 kg) per day and a batch is expected to be complete in 5 minutes, then the mass of material processed per batch was determined using Equation (6) reported by Gbabo (2005).

$$M_b = \rho_g \left(\frac{V_d \times T_b}{T_T} \right) \quad (6)$$

where, M_b = mass of material to be processed at a time (kg); ρ_g = bulk density of the grains (kg m^{-3}); V_d = volume of material to be processed per day (m^3); T_T = total time required to process the material (minutes), T_b = expected time to process the materials at a time (minutes).

2.3.3 Determination of mass of blending blades

The mass of the blending blades is vital in computation of the power requirement of the machine and it was computed using the following Equations (7) and (8) reported by Gbabo (2005).

$$M_B = \rho_B \times V_B \quad (7)$$

$$M_B = \rho_B \times [N_B(L_B \times B_B \times T_B) + \pi h_{hB}(r_{HBE}^2 - r_{HBI}^2)] \quad (8)$$

where, M_B = the mass of the blending blade (kg); V_B = the volume of blending blade (m^3); ρ_B = the density of blade (stainless steel) (kg m^{-3}); N_B = the number of horizontal blades (m); L_B = the length of horizontal blade (m); B_B= the breadth of horizontal blade (m); T_B = the thickness of horizontal blade (m); h_{hB} = the height of blade housing (m); r_{HBE} = the total radius of blade housing (m); r_{HBI} = the internal radius of blade housing (m); π = constant = 3.14.

2.3.4 Mass of the central shaft

The mass of the central shaft is important in computation of power needed by the machine and was determined from the relationship reported by Gbabo (2005) as Equations (9) and (10):

$$M_{CS} = \rho_{CS} V_{CS} + M_{SB} \quad (9)$$

$$M_{CS} = \rho_{CS} \left(\frac{\pi d^2 CS}{4} \right) L_{CS} + M_{SB} \quad (10)$$

where, M_{CS} = mass of the central shaft (kg); ρ_{CS} = density of the central shaft (kg m^{-3}); V_{CS} = volume of the central shaft (m^3); d_{CS} = diameter of the central shaft (m); L_{CS} = length of the central shaft (m^3); M_{SB} = mass of the bearing on the shaft (kg).

But the diameter of the central shaft was computed using the established Equation 11stated by Khurmi and Gupta (2005):

$$d^3 = \frac{16}{\pi S_S} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (11)$$

where, d = expected diameter of shaft (m); M_t = belt torque (Nm); M_b = bending moment (Nm); K_b = shock and fatigue factor applied to bending moment (constant); K_t = shock and fatigue factor applied to torsional moment (constant); S_S = permissible shear stress of the shaft (MPa).

2.3.5 Second polar moment of area of the shaft

The second polar moment of area of the central shaft is essential in determination of the resistance of the shaft to bending and deflection and was computed as reported by Gbabo and Igbeka (2003) as Equation (12).

$$J = \frac{\pi ds^4}{32} \quad (12)$$

where, J = second polar moment of area (m^4); π = constant = 3.14; d_s = diameter of shaft (m).

2.3.6 Size of machine pulley

For proper selection of the machine speed four different sizes of pulley were used. The sizes of the machine pulleys were determined by Equation (13) as reported by Gbabo (2005).

$$N_1 D_1 = N_2 D_2 \tag{13}$$

where, N_1 = revolution per minute of electric motor (rpm); D_1 = pulley diameter of electric motor (m); N_2 = revolution per minute of the machine; D_2 = diameter of machine pulley (m).

2.3.7 Stress in the central shaft

The stress in the central shaft due to the action of the centrifugal force was computed in order to assist in the determination of the thickness of the shaft. It was determined using the Equation 14 as reported by Gbabo and Igbeka (2003).

$$\delta_b = \left(\frac{2\pi N}{60}\right)^2 \left(\frac{M_g}{2l_b \times g}\right) \tag{14}$$

where, δ_b is the stress on the shaft (N m^2); M_g = the total mass of material on the shaft (kg); N = the revolution per minute (rpm); I_b = the length of the shaft (m); π = constant (3.14); g = the acceleration due to gravity (m s^{-2}).

2.3.8 Twisting moment

The high rotating speed of the shaft is influenced by twisting moment. The twisting moment of the shaft was determined by Equation (15) as reported by Gbabo and Igbeka (2003).

$$M_t = \frac{60W}{2\pi N} \tag{15}$$

where, M_t = twisting moment (Nm); N = speed of rotation of the shaft (rpm); W = power transmitted (W); π = constant (3.14).

2.3.9 Design of the pasteurizer

The expected machine output at a time is 15 liters of aqueous soya milk. After three operations 45 liters will be produced. The volume of the pasteurizer was designed based on 55 liters of soya milk (45 liters for milk and 10 liters for safety). It was determined using the Equations (16)-(17) reported by Gana (2011).

$$V_{mj} = \pi r_p^2 h_p \tag{16}$$

$$h_p = \frac{V_{mj}}{\pi r_p^2} \tag{17}$$

where, h_p = the height of the pasteurizer (m); V_{mj} = the volume of the milk jacket (m^3); r_p = the radius of the pasteurizer (m).

2.3.10 Design of the water jacket

The volume of water required to heat the milk was assumed to be equal to the volume of the milk. Therefore the volume of the water jacket was computed by Equation (18) as reported by Gana (2011) and from preliminary investigation.

$$V_J = 2(V_{mj}) \tag{18}$$

where, V_J = the volume of the jacket (m^3); V_{mj} = the volume of the milk jacket (m^3).

2.3.11 Thickness of insulation

The thickness of the insulating material is computed by Equation (19).

$$q / l = {2\pi k(T_4 - T_5)} \Big/ {Ln(r_5 / r_4)} \tag{19}$$

By making r_5, the subject of the formula Equation (19) becomes Equations (20)-(22):

$$Ln(r_5 / r_4) = {2\pi k(T_4 - T_5)} \Big/ {q / l} \tag{20}$$

$$r_5 = r_4 \times \left(e^{\frac{2\pi K_4 (T_4 - T_5)}{q/l}} \right) \tag{21}$$

But $\Delta r = r_5 - r_4$, therefore, therefore

$$r_5 = r_4 \times \left(e^{\frac{2\pi K_4 (T_4 - T_5)}{q/l}} \right) - r_4 \tag{22}$$

where, q is the heat loss through the vessel (W m^{-1}); r_4 is the external radius of the water jacket (m); r_5 is the radius of the insulating material fiber glass; r_6 is the radius of outer casing stainless steel (m); k_4 is the thermal conductivity of insulating material fiber glass (W/(m K)); k_4 is the thermal conductivity of mild steel material (W/(m K)); L is length of the pasteurizer (m); Δr is thickness of the insulating material (m); T_4 is the internal temperature of water contained in the water jacket (°C); T_5 is the external temperature of the environment (room temperature 30°C was assumed).

Heat loss through the pasteurizer

The heat loss through the pasteurizer was calculated as following Equation (23).

$$\frac{q}{L} = \frac{(T_1 - T_5)}{\frac{1}{2\pi(k_1)L}\ln\left(\frac{r_2}{r_1}\right) + \frac{1}{2\pi(k_2)L}\ln\left(\frac{r_3}{r_2}\right) + \frac{1}{2\pi(k_3)L}\ln\left(\frac{r_4}{r_3}\right) + \frac{1}{2\pi(k_4)L}\ln\left(\frac{r_5}{r_4}\right) + \frac{1}{2\pi(k_5)L}\ln\left(\frac{r_6}{r_5}\right)} \tag{23}$$

where, q is the heat loss through the vessel (W m^{-1}); k_1 is the thermal conductivity of stainless steel (W/(m K)); r_1 is the radius of the milk chamber (m); r_2 is the external radius of the milk chamber (m); k_2 is the thermal conductivity of water (W/(m K)); r_3 is internal radius of the water jacket (m); r_4 is the external radius of the water jacket (m); k_3 is the thermal conductivity of stainless steel (W/(m K)); r_5 is the radius of the insulating material fiber glass (m); r_6 is the radius of outer casing stainless steel (m); k_4 is the thermal conductivity of insulating material fiber glass (W/(m K)); k_5 is the thermal conductivity of mild steel material; L is length of the pasteurizer (m); T_1 is the internal temperature of milk contained in the internal jacket (°C); T_5 is the external temperature of the environment (room temperature 30°C was assumed).

Table 1 Summary of design calculations

S/N	Parameters	Formula	Calculated value
1	Mass of soya beans to be processed at a time	$M_b = \rho_g\left(\frac{V_d \times T_b}{T_T}\right)$	1.5 kg
2	Mass of blade assembly	$M_B = \rho_B \times V_B$	0.05 kg.
3	Diameter of the shaft	$d^3 = 16/\pi S_S\sqrt{(K_bM_b)^2 + (K_tM_t)^2}$	0.02 m
4	Expected thickness of blade	$\delta_b d_b / 2S_S$	0.002 m
5	Twisting moment	$M_t = \frac{60W}{2\pi N}$	25.12 Nm
6	Mass of the central shaft	$M_{CS} = \rho_{CS}V_{CS}$	1.2 kg
7	Second polar moment area the shaft	$J = \pi ds^4/32$	1.48×10^{-8} m^4
8	Angular velocity (ω)	$2\times\pi\times N/60$	15.35 rad min^{-1}
9	Torque (τ)	$F \times r_d$	7.7 Nm
10	Total force (N)	$M \times r_d \times \omega^2$	76.7 N
11	Power required by the machine	$2\times\pi\times N\times\tau/60$	1.47 kW
12	Selected of electric motor capacity	$\frac{2\times\pi\times N\times\tau}{60}$	2hp
13	Thickness of insulating material	$\Delta r = r_5 - r_4, r_5 = r_4 \times (e^{\frac{2\pi K_4(T_5-T_4)}{q/l}}) - r_4$	0.05 m
14	Heat loss through pasteurizer	$\frac{q}{l} = \frac{T_1 - T_5}{\frac{1}{2\pi K_1L}\ln\left(\frac{r_2}{r_1}\right) + \frac{1}{2\pi K_2L}\ln\left(\frac{r_3}{r_2}\right) + \frac{1}{2\pi K_3L}\ln\left(\frac{r_4}{r_3}\right) + \frac{1}{2\pi K_4L}\ln\left(\frac{r_5}{r_4}\right)}$	80.23 W m^{-1}

2.4 Materials selection

Small scale soya milk production and pasteurization plant was designed and fabricated in the Federal Polytechnic Bida using stainless steel materials. All parts of the plants that will get in direct contact with the product were made with stainless steel materials in order to avoid contamination (Gbabo et al., 2012).

2.5 Treatments, measurements and statistical analysis

Two different experiments were conducted to test the performance of the mini plant. In the first experiment; the performance of the milling section was tested while in the second experiment; the performance of the pasteurizer was tested.

2.5.1 Testing of the milling unit

Experimental setup and procedure for developing the design matrix

In this study, central composite rotational design (CCRD) of response surface method (RSM) was tested at five levels with three independent variables; steeping time, blade type, and speed of blending in order to investigate the blending efficiency of the machine. The experiment consists of 20 experimental runs (2^k+2k+m, where k represents the number of factors independent variables and m represents repeated centre point), involving eight factorial points (2^3), six axial point (2 × 3), and six replicated centre points at zero level (Anuonye, 2006; Aworanti et al., 2013). The matrix transformation of the design is shown in Table 2.

Determination of machine blending efficiency

This is the measure of the degree by which the grains are reduced in size and was determined by Equation (24) as reported by Nwaigwe et al. (2012).

$$E_B = \frac{A}{MT} \times 100 \quad (24)$$

where, E_B is the blending efficiency (%); A is the amount of the material passed through the sieve (kg); *MT* is the total weight of the material feed into the machine (kg).

2.5.2 Testing of the pasteurisation unit

In this experiment three different soya milk samples were subjected to microbial load analysis, coliform and mould count after each 24 hours for the period of 168 hours (Gesinde et al., 2008; Adeleke et al., 2000). The samples used were sample (A) produced using traditional method, (B) produced using the mini plant and stored at room temperature and (C) sample produced using the mini plant and refrigerated.

Microbial load analysis

Nutrient agar was used as the growth medium. The agar was prepared according to manufacturer's specifications. The standard tenfold serial dilution technique was employed to dilute each sample up to the 10 level. The plates were then inoculated with 1 mL of the 10^5 dilutions and then methods incubated at 37°C for 24 hours after which the number of viable cells was counted using digital colony counter (Gallenkemp England). The counts were converted to microbial load using the Equation (25) as reported by Gesinde et al. (2008)

$$M_L = \frac{N}{V} \times R \tag{25}$$

where, M_L is microbial load (cfu/mL); N is number of colonies; V is value of dilution (cfu); R is dilution factor (mL).

Presumptive coliform test (PCT)

This test gave an estimate of most probable number (MPN) of coliform bacilli per 100 mL of each soymilk sample. Every sample was diluted 1 in 100 in 200 mL. of sterile distilled water and subjected to multiple tube technique of PCT. The bile-based medium used was MacConkey broth (Difco International) in double- and single-strength concentrations appropriately. Tests that showed acid and gas production after 48 hrs of incubation at 35°C were considered positive for coliform bacilli (Adeleke et al., 2000).

Faecal coliforms and detection of *E.coli*.

All the positive tests in the PCT and an overnight broth culture of *E. coli* NCTC 97001 were subcultured in loop-full, each into MacConkey broth and incubated at 44°C to 45.5°C in an electro thermal water-bath for 48hrs. The subcultures that produced acid and gas as evidence of faecal coliforms were streaked each on MacConkey agar plate and incubated at 37°C for 24 hrs. Reddish pink colonies that stained Gram-negative rods as the *E. coli* control culture were subjected to Indole Methyl red Voges-Proskauer Citrate (IMViC) tests for differentiating the enteric coliforms. *E. coli*was detected as indole and methyl red positive but Voges-Proskauer and Citrate test negative (Adeleke et al., 2000).

3 Results and discussions

3.1 Blending efficiency

The effects of independent variables; blade configuration, steeping time and speed on the blending efficiency is presented in Table 2. The blending efficiency ranged between 56.4% and 88.36%. The highest blending efficiency of 88.36% was obtained from combination of steeping time of 12 hours, three blades assembly and speed of 1400 rpm while the least efficiency of blending of 56.4% was obtained from combination of steeping time of 6 hours 38 minutes, four blades assembly and speed of 1200 rpm. This result is similar to crushing efficiency of 82.3% reported by Nwaiegwu et al. (2012).

Table 2 Effects of steeping time, blade type and speed on blending efficiency

Std	run	Steeping time, hrs	Blade type (No)	Speed of blending, rpm	Blending efficiency, %
9	1	6.64	4	1200	56.4
10	2	13.36	4	1200	70.27
14	3	10	4	1536	81.74
19	4	10	4	1200	66.33
17	5	10	4	1200	66.12
8	6	12	5	1400	85.12
4	7	12	5	1000	58.69
2	8	12	3	1000	63
13	9	10	4	864	58.54
5	10	8	3	1400	67.72
15	11	10	4	1200	64.64
16	12	10	4	1200	65.12
1	13	8	3	1000	61.85
3	14	8	5	1000	59.21
20	15	10	4	1200	64.17
6	16	12	3	1400	88.36
7	17	8	5	1400	63.06
12	18	10	6	1200	66.47
18	19	10	4	1200	64.64
11	20	10	2	1200	75.17

Response surface for blending efficiency with respect to speed of blending and blade type

The response surface for blending efficiency is presented in Figure 5. The blending efficiency increased from 42% to 84.7% as the speed of blending increase from 1000 to 1400 rpm. This could be due to increased in impact force, cutting and shearing actions of the blade with increased in rotational speed. This agreed with the result of an earlier study by Gbabo et al. (2016) where rotational speed was found to be a key factor in size reduction of solid materials. It was obvious that the blending efficiency decrease from 42% to 30% with increased in blade configuration from three to five blades assembly.

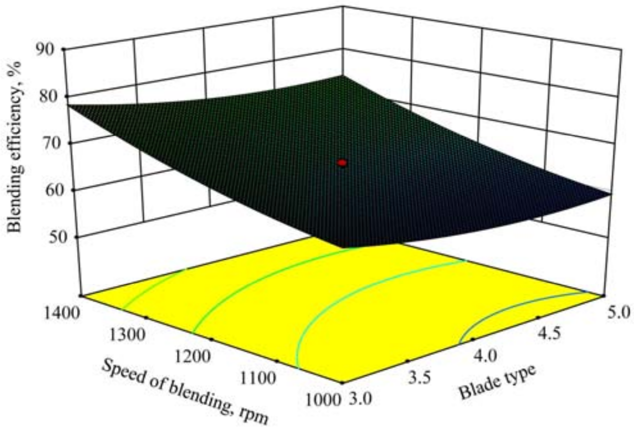

Figure 5 Response surface of blending efficiency with respect to speed of blending and blade type

Response surface for blending efficiency with respect to steeping time and blending and blade type

The blending efficiency increased from 62% to 73% as the steeping time increased from 8 to 12 hours. This could be due to increased in softness of the soya beans as it absorbs moisture. This agreed with the result of an earlier study by Gana (2011) where steeping of soya bean was found to soften the seed and increase its milling efficiency.

3.2 Testing of the pasteurization unit

The samples of milk obtained were subjected to microbial count (bacteria, coliform and mould) analysis and comparisons were made among samples produced using the developed mini plant and stored under room temperature, samples produced using the developed mini plant and stored under temperature of 4°C and sample produced and stored under traditional with some standard values.

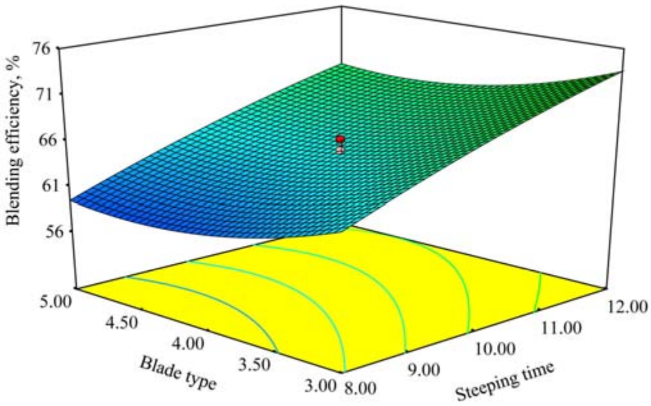

Figure 6 Response surface of blending efficiency with respect to steeping time and blending and blade type

Microbial load

The total viable count (TVC), coliform and mould values of the soya milk samples are presented in Table 3. The values ranges from 1.13×10^3 to 4.6×10^3 CFU mL^{-1} for TVC, 3.83×10^3 to 1.75×10^3 CFU mL^{-1} for coliform and 2.12×10^2 to 6.2×10^7 CFU mL^{-1} for mould count. The highest value of TVC of 3.4×10^3 CFU mL^{-1} obtained from soya milk produced using local method on the first day of production is an indicative that the product would prone to deterioration. This value increased to 4.46×10^7 CFU mL^{-1} on the second day, which makes the milk bad for consumption as reported by Nwobosi et al. (2013). The value of TVC of 3.31×10^3 CFU mL^{-1} was obtained from milk samples pasteurized and stored under room temperature. Nwobosi et al. (2013) reported that the major disadvantage of spoilage organisms in the milk is that they easily multiply and cause unwanted effects.

This value was obtained on the second day of storage as on the first day there was no any significant effects of TVC dictated. On the third day the value increases to 2.2×10^7 CFU mL^{-1}. This high value is an indication that the milk is no more good consumption. On the other hand samples pasteurized and stored under the temperature of 4°C were save and good for consumption up to the fourth day of production. They are fairly good on the fifth day and became bad for consumption on the sixth day. These agreed with the report of Worku et al. (2015), where milk sample containing 5.00×10^3 CFU mL^{-1} of bacteria is classified as good for consumption, 1.00×10^4 to 4.00×10^5 CFU mL^{-1} as fairly good. Levels up to 2.00×10^6 and 2.00×10^7 CFU mL^{-1} are classified as acceptable and bad for consumption respectively. According to Brooks et al.

(2003), the higher the concentration of pathogenic micro-flora in a product the higher chances of spoilage of that products. The high concentration of coliform in soya milk produced using available method is further confirmation that it has a lower keeping quality as compared with the other two products. Also its high level of mould content is indicative that its wholesomeness is questionable. On the other hand, the insignificant level or absent of pathogenic microflora in pasteurized samples stored under the other two condition of room temperature and refrigerator for the first two and four days respectively, is an indication that are good for consumption. Moulds are problematic in foods as that they discolour food surfaces, cause off odours and off flavours as well as produce toxins in certain instances (Momoh et al., 2011).

Table 3 Microbial load analysis of soya milk samples

S/N	Number of hours	Method	TVC, CFU mL^{-1}	Coliform, CFU mL^{-1}	Mould, CFU mL^{-1}	Remark
1	0	A	3.43×10^{3}	1.13×10^{3}	6.3×10^{3}	Good
		B	IN	IN	IN	Insignificant
		C	IN	IN	IN	Insignificant
2	24	A	4.6×10^{7}	1.75×10^{7}	6.2×10^{7}	Bad
		B	3.31×10^{3}	1.16×10^{3}	5.9×10^{3}	Good
		C	IN	IN	IN	Insignificant
3	48	A	BD	BD	BD	Bad
		B	2.2×10^{7}	6.3×10^{6}	4.29×10^{7}	Bad
		C	IN	IN	IN	Insignificant
4	72	A	BD	BD	BD	Bad
		B	BD	BD	BD	Bad
		C	1.13×10^{2}	3.83×10^{1}	2.12×10^{2}	Good
5	96	A	BD	BD	BD	BD
		B	BD	BD	BD	BD
		C	1.83×10^{3}	5.12×10^{2}	3.66×10^{3}	Good
6	120	A	BD	BD	BD	Bad
		B	BD	BD	BD	Bad
		C	5.21×10^{5}	1.48×10^{5}	8.28×10^{5}	Fairly good
7	144	A	BD	BD	BD	Bad
		B	BD	BD	BD	Bad
		C	2.82×10^{7}	7.89×10^{6}	5.33×10^{7}	Bad

Note: A = Available Method, B = Pasteurizes stored at 27°C ±2°C, C = Pasteurizes stored at 4°C. IN = Insignificant level, BD = Bad.

4 Conclusions

The mini plant was designed, fabricated (using stainless steel materials) and tested. The findings of the study were analysed and these conclusions were made. The machine input capacity was 68 kg of grains per 8hrs in a day and its output was 500 liters of beverages per 8hrs in a day.

The interactive effects between the machine parameters showed that blending efficiency increased with increase in steeping duration from 6 to 12 hours and speed of blending from 1000 to 1400 rpm. But it decreases with increase in blade type (number) from two blades assembly to five blades assembly.

The optimum blending efficiency of 88.16% was obtined from combination of three blades assembly, steeping duration of 12 hours and speed of 1400 rpm. The selected pasteurization temperature and time were 84°C and 30 seconds. The machine was able to increase shelf life of raw soya milk from 1 to 2 days when stored under room temperature and to 6 days when stored at temperature of 4°C.

Acknowledgement

We wish to thank the Tertiary Education Trust Fund (TETFund) for providing the grant for this research work.

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