

# Design a VAT milk pasteurizer in Tanzania

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## Abstract

The project presents “Design of micro-VAT milk pasteurizer” The microcontroller temperature regulator provides an automated way of controlling the temperature of a given pasteurizer for pasteurizing the milk at a given temperature (63 °C for 30 minutes). This project is realizable via temperature sensing, signal conditioning and relaying. The temperature sensor senses the current of the said pasteurizer, send it to the ADC (Analogue to Digital Converter) the digitized signal is then sent a controller which through the help of a programmed input (software), does the comparison and control by sending a feedback signal to the heating element thereby bringing about the regulation of the temperature of the said pasteurizer. A great advantage of this project is that it provides automated, and it is reliable, if there can be a constant power supply to the system. It is also economical in construction. Agricultural products such as milk in their raw state have harmful organisms such as viruses and bacterial that are known for causing diseases when consumed. For safe consumption and healthy leaving, this organism needs to be reduced or eliminated.

## Introduction

Tanzania is among the fastest growing dairy nation in Africa, accounts for about 1.4% of global cattle population and 11% of Africa cattle population [1]. With increase in population and enhancement in lifestyle of the people the demand for the dairy and food products is increased day by day. Milk and its products are fundamental in human nutrition. Milk contains essential minerals, high quality protein, fats and vitamins. These makes milk to be a very important and complete diet on its own. Milk is a perishable foodstuff which when improperly handled is an excellent medium for the growth of micro-organisms which cause spoilage [2]. Milk is considered safe for consumption when it contains  $5 \times 10^6$  bacterial per ml [3]. Milk products and their cost are determined by an effective design of a heat treatment plant. The qualities of consumables and human lifestyle have been affected to a high degree by the application of heat transfer. Greiner and Bussick, (2000) opined that the understanding and control of heat flow through heat exchangers, thermal insulations and other supporting devices are frequently used in solving basic or fundamental human problems which have made heat transfer a field of importance to Engineering.

A process named after scientist Louis Pasteur which uses the application of heat to destroy human pathogens in foods. For the dairy industry, the terms “pasteurization”, “pasteurized” and similar terms shall mean the process of heating every particle of milk or milk product, in properly designed and operated equipment, at a specific temperature and held continuously at or above that temperature for at least the corresponding specified time. Pasteurization is a mild heat treatment applied to ensure microbial safety and to supply milk with longer shelf life. In this process, milk is heated at 72 °C for 15s or 63 °C for 30min [4]. In liquid food industries, heat exchangers for many years have become an essential component in the process line Temperature control loops are often used with heat exchangers in a heat transfer process in other to maintain an accurate and stable temperature. Temperature is a critical parameter to the health and product quality in the case of food heat treatment. The consumption of contaminated liquids and other liquid foods (milk inclusive) has been attributed to the cause of about 80% of infectious diseases including diarrhea, typhoid, cholera in developing countries. Heat treatment of liquid food is important because the death of over 400 children per hour in the world and nearly more than four million children per year has been attributed to diarrhoea by the World Health Organization (WHO). The direct consumption of over the air water and liquid food without heat treatment has created tremendous stress on both huge medical bills and health which in turn results into high morbidity. About a thousand faecal coli

ISSN: 2694-4421



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Submission: 📅 September 21, 2020

Published: 📅 April 09, 2021

Volume 1 - Issue 5

How to cite this article: Vicent Marwa.  
Design a VAT milk pasteurizer in Tanzania.  
Academic J Eng Stud. 1(4). AES.000525.  
2021.  
DOI: [10.31031/AES.2021.1.000525](https://doi.org/10.31031/AES.2021.1.000525)

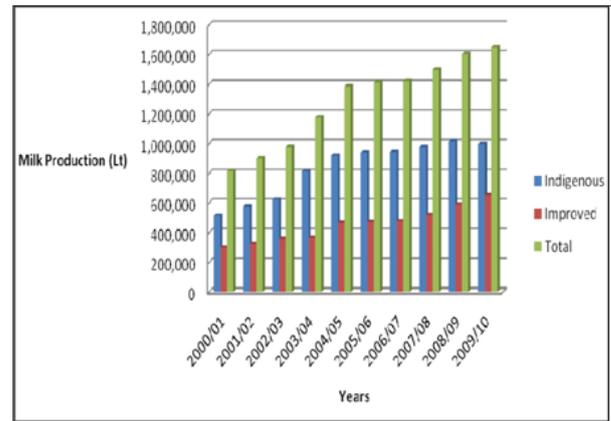
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form per decilitre is found to be contained in surface water and this is due to pollution from animals and human life activities.

Speer (1998) acknowledged that the consumption of fresh raw milk led to the transmission of cow diseases such as typhoid, brucellosis and tuberculosis. In order to make surface water and dairy products safe for human consumption, there is therefore needed to have a design which will heat treat these raw consumables thus, pasteurization comes in. Milk production in Tanzania is carried out under two major production systems. These are the traditional and the dairy production systems. Within the traditional system milk is mainly produced by indigenous cattle which are kept for multipurpose objectives. The traditional system is characterized by low productivity, but high per unit of invested money. The milk produced is mostly consumed locally and quite often a significant amount is left for the calves because of the lack of markets. Within the dairy systems, improved dairy cattle which are mainly crosses of Friesian, Jersey and Ayrshire to the Tanzania Shorthorn Zebu are the main dairy cattle breeds in use (MLFD, 2011). Low consumer demand for milk and dairy products due to high retail prices and low incomes of the population which hinders the growth of agricultural production. One of the ways to overcome this contradiction is the development of the free market competition. According to Elliot et al. (2007) the actual definition of pasteurization is the heating of milk to specific temperature for a specific time to reduce undesirable enzymes and bacterial to negligible level. It is important that pasteurization is a function of time and temperature not just temperature. Imele et al. [5] reported that pasteurization is a process to prevent the spoilage of milk. It has been used since the early 1900s (heating raw milk to 72 °C for 15 minutes). It is expected to remove/reduce microorganisms from milk.

### Problem statement

Traditional milk production in Tanzania, milk is mainly produced by indigenous cattle which are kept for multipurpose objectives. The indigenous cattle which constitute the traditional herd are mainly kept in the Central, Northern, Southern Highlands, and Western parts of the country (Figure 1). The traditional system is characterized by low productivity, but high per unit of invested money. In addition, production costs are relatively low. Due to the remoteness and poor infrastructure, collection of milk and marketing constitute the largest bottlenecks. Hence, the milk produced is mostly consumed locally and quite often a significant amount is left for the calves because of the lack of markets. However, some producers who depend on milk for their cash income are willing to exploit the available opportunity in marketing their produce, for example, some traditional producers residing mainly in peri-urban areas near towns or urban centers such as those in the Tukuyu, transport milk by bicycles over long distances, for sale at some collection centers located along the major road highways. Through observations and realization of milk association in Tukuyu area. The researcher discovered that the livestock keeping are experiencing difficulties in milk preservation and therefore a need for design machine to overcome milk spoilage.



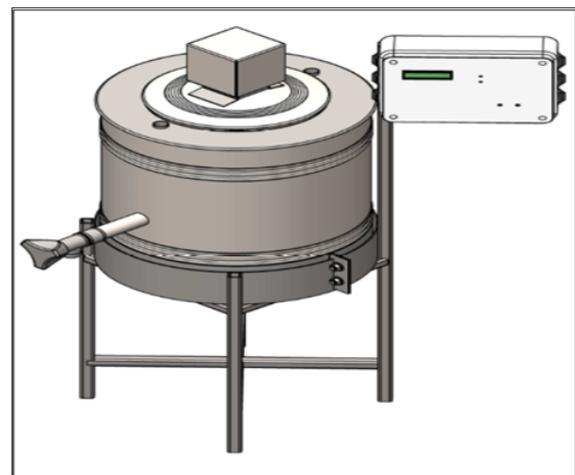
**Figure 1:** Production of milk 2000/01-2009/10 (MLFD, 2011).

### Method and Equipment

Equipment and method used for studies on electrical water heating system in water jacket for pasteurization of milk. The experiment on performance evaluation were carried out in the Mechanical and Industrial Engineering Department at the college of Mbeya University of Science and Technology, MUST.

### Machine description

The mini plant was constructed using stainless steel material and it made of the following components (Figure 2).



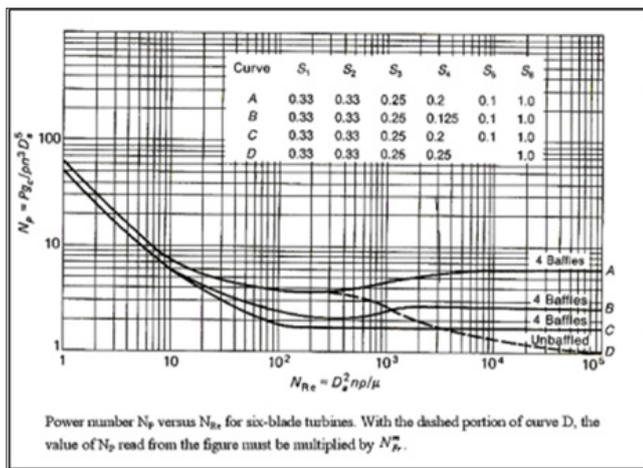
**Figure 2:** Complete assembly of machine source (Researcher).

**Heating unit:** The vat pasteurizer jacket is a double-walled covering. In the space between the walls, circulating water which heat the product in the vat. This unit is made up of the following sub-component parts, milk tank, water jacket, coil heater milk inlet and outlet valve, water inlet and outlet valve and insulation case.

**Agitation assembly:** An agitator is designed to keep milk or milk product moving at all times by running constantly during the pasteurization cycle. This results in uniform product and temperature throughout the vat. This unit is made up of the following sub-component parts motor, shaft and bleed.

**Control system:** A constant pasteurization temperature is maintained by a temperature controller acting on the heater. Any tendency for the product temperature to drop is immediately detected by a sensor in the product line before the holding tube. The sensor then changes the signal to the controller, which turns on the water heater to rise the temperature of water. This increases the temperature of the circulating water and stops the temperature drop in the product.

**Frame and support:** The design of the stand of VAT pasteurizer machine is essential for this work. Stainless steel material was used in design based on its availability, strength, appearance, food processing standard, and corrosion resistance. The design was based to determine forces acting on machine (Figure 3).



**Figure 3:** Power curve for turbine type agitator (Saeed Asiri, et al., 2012).

**Mode of operation of the machine**

The method used in pasteurization is called holding method in which milk or milk product is rapidly heated, but the temperature is not less than 63 °C and not more than 66 °C, it retained at that temperature for not less than 30 minutes. Therefore, working operation is to maintain milk temperature in the range of 63 °C-66 °C for not less than 30 minutes it is done by heating milk to 63 °C after reaching that temperature we switch off electric heater automatic and start counting time with aid of Arduino, temperature sensor and Liquid Crystal Display (LCD).

**Materials selection**

Small scale soya milk production and pasteurization plant was designed and fabricated in the workshop at Mbeya University of Science and Technology (MUST) 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 [6]; (Figure 3).

**Testing and statistical analysis**

Experiments were conducted to test the performance of the mini plant. Two different cow milk samples were subject for the period of 168 hours. The samples used were sample (A) raw milk stored at room temperature, (B) raw milk and stored at temperature below

4 °C (C) pasteurized milk and stored at room temperature and (D) pasteurized milk and stored at temperature below 4 °C.

**Design analysis of machine components**

10 liters capacity batch pasteurizer is analyzed below with 304 grade stainless steel. The size was selected considering the daily quantities of marketed milk by trader’s in Tukuyu Table 1. It has required to find the quantity of heat required to rise the temperature of water for successive pasteurization, geometric parameters of the water jacket (water bath thickness) and design of agitator with the following preset parameters.

**Table 1:** Initial design parameter.

Item No	Parameters	Description
01	The initial temperature of milk	37 4 °C
02	The final temperature of milk	65 4 °C
03	Volume of milk processed	10 Litres
04	Density of milk	1027kg/m <sup>3</sup>
05	Kinematics viscosity	0.7968×10-6m <sup>2</sup> /s
06	Heat capacity of milk	3.93Kj/kgK

**Geometric parameter of tanks**

$$V = \pi / 4D^2 h \quad (1)$$

Where,

V= Volume of tank

D= Diameter of tank

h= height of tank

**Geometric parameter of milk tank**

$$0.0102 = \pi / 4D^2 \times 0.8D$$

$$D=253.2\text{mm} \cong 260\text{mm}$$

From equation (2)

$$h=0.8 \times 260$$

$$h=208\text{mm}$$

**Geometric parameter of water tank**

Since all tank are cylindrical assume the water jacket 50 mm wider than the milk tank

$$\text{Diameter of water tank } D=360\text{mm}$$

$$\text{Height of water tank } h=258\text{mm}$$

**Volume of water in jacket**

$$V_w = \text{volume of water tank} - \text{volume of milk tank} \quad (2)$$

$$V_w = \frac{\pi}{4} \times 0.36^2 \times 0.258 - \frac{\pi}{4} \times 0.26^2 \times 0.208$$

$$V_w = 0.0182\text{m}^3 \quad (\text{Table 2}).$$

**Analysis of heat transfer**

**Table 2:** Dimensional specification of milk bath and water jacket.

No.	Component of Pasteurizer	Material used	Items/Units	Dimension in (mm)
1.	Water tank	Stainless steel 304 grade	Diameter	360
			Height	258
2.	Milk tank	Stainless steel 304 grade	Diameter	260
			Height	208
3.	Insulation	Fiber glass insulation	Thickness	50
4.	Auxiliary heater (2kW)	Nickel-chromium resistance wire	Length of immersion rod	200

**The quantity of heat spent to heat milk**

$$Q = G_m \times C_m \times \Delta T \quad (3)$$

Where:

G<sub>m</sub> = The mass of heated milk (kg)

C<sub>m</sub> =Milk heat capacity (KJ/kg)

ΔT =change in temperature in milk.

$$G_m = \rho \times V \quad (4)$$

$$G_m = 1027 \times 0.01$$

$$G_m = 10.27 \text{kg}$$

Specific heat capacity of milk depends on the temperature. Heat capacity of milk at the average temperature of 51 °C is C<sub>m</sub>=3.973kJ/kg.K

$$Q = 10.27 \times 3.973 \times (65 - 37)$$

$$Q = 1142.476 \text{kJ}$$

The motivity of thermal process is temperature difference. According to the second law of thermodynamic, heat transfer will carry out from the warmer body to a less heated. The physical sense of heat transfer is the exchange of energy between molecules, atom, and free electron, this means that all the heat lost by the water goes into heating milk.

$$\text{Heat lost by water} = \text{Heat gained by milk} \quad (5)$$

$$1142.476 = 15.2 \times 4.2 \times (100 - t_0)$$

So, equilibrium temperature of water will be t<sub>0</sub> = 81.2 °C

**Logarithmic mean temperature difference**

In the analysis of heat exchanger, it is usually convenient to work with the logarithmic mean temperature difference LMTD, which is an equivalent mean temperature difference between the two fluid for the entire heat exchanger.

$$\text{Large temperature difference } \Delta T_l = 100 \text{ } ^\circ\text{C} - 37 \text{ } ^\circ\text{C} = 63 \text{ } ^\circ\text{C}$$

$$\text{Small temperature difference } \Delta T_s = 82.1 \text{ } ^\circ\text{C} - 65 \text{ } ^\circ\text{C} = 17.1 \text{ } ^\circ\text{C}$$

$$LMTD = \frac{\Delta T_l - \Delta T_s}{\ln \frac{\Delta T_l}{\Delta T_s}} \quad (6)$$

$$LMTD = \frac{63 \text{ } ^\circ\text{C} - 17.1 \text{ } ^\circ\text{C}}{\ln \frac{63 \text{ } ^\circ\text{C}}{17.1 \text{ } ^\circ\text{C}}}$$

$$LMTD = 35.198 \text{ } ^\circ\text{C}$$

Average water temperature in heat exchanger jacket t<sub>a.w</sub>

$$t_{a.w} = \frac{100 + 82.1}{2} = 91.05 \approx 91 \text{ } ^\circ\text{C}$$

Average milk temperature in the bath t<sub>a.m</sub>

$$t_{a.m} = \frac{37 + 65}{2} = 51 \text{ } ^\circ\text{C}$$

Amount of heat spent on heating the milk can be found with

$$Q = K \times \Delta T \times F \quad (7)$$

Where

Q= Amount of heat spent on heating the milk

ΔT = Temperature difference

K= Coefficient of heat transfer

F = Heat exchanger area

The heat transfer coefficient can be found with

$$K = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}} \quad (8)$$

Where

α<sub>1</sub>=coefficient of heat transfers out of the water to the wall

α<sub>2</sub>=coefficient of heat transfers from the wall to the product

λ= thermal conductivity of stainless food steel

δ= thickness of the material

Convection heat transfer coefficient α

$$Nu = 0.03 \times Re_w^{0.8} \times Pr_w^{0.43} \times \left( \frac{Pr_w}{Pr_{wall}} \right)^{0.25} \quad (9)$$

Where:

Nu= nusselt number, dimensionless heat transfer coefficient

Re<sub>w</sub> = Reynolds number, fluid motion criterion regime

Re<sub>w</sub> = Prandtl number for liquid, dimensionless characteristics of thermal properties of the fluid

Pr<sub>wall</sub> = Prandtl number for liquid in the boundary layer

Reynold number

$$Re = \frac{w \times D}{\nu} \quad (10)$$

Where:

Re = Reynold number for liquid in the tube

w = liquid velocity in the tube of the heat exchanger (ms<sup>-1</sup>)

D = The heat exchanger tube diameter(m)

ν = The kinematic viscosity of liquid (m<sup>2</sup>s<sup>-1</sup>)

Convection thermal conductivity

$$\alpha = \frac{Nu \times \lambda}{D} \quad (11)$$

Where

α = Convection thermal conductivity

Nu = Nusselt number, dimensionless heat transfer coefficient

λ = Thermal conductivity of liquid

**Coefficient of heat transfers out of the water to the wall**

To improve the heat transfer from the water to the wall of heat exchanger need to create a turbulent flow of fluid motion [7].

Velocity of water in jacket we will mark as w<sub>w</sub> = 0.5ms<sup>-1</sup>

Kinematic viscosity of water at average temperature of 91 °C is ν<sub>w</sub> = 0.3377 × 10<sup>-6</sup> M<sup>2</sup> / C

Diameter of water jacket 50mm

$$Re = \frac{0.5 \times 0.05}{0.3377 \times 10^{-6}}$$

$$Re = 74030.204$$

Re > 4000 movement of water in the jacket is considered to be turbulent [8]

Prandtl number of waters in the exchanger with an average temperature of 91 °C is Pγ<sub>w</sub> = 2.028

In the boundary layer water temperature would be 2 °C below than in existing the heat exchanger [7]

Prandtl number of water in the boundary at temperature of 80 °C is Pγ<sub>wall</sub> = 2.516

$$Nu = 0.03 \times 74030.2^{0.8} \times 2.028^{0.43} \times \left(\frac{2.028}{2.516}\right)^{0.25}$$

$$Nu = 302.88$$

Thermal conductivity of water depends on temperature [9]. Thermal conductivity of water at average temperature of 91 °C λ<sub>w</sub> = 0.6782 W/mK

$$\alpha_1 = \frac{302.88 \times 0.6782}{0.05}$$

$$\alpha_1 = 4108.26W / m^2 .K$$

**Coefficient of heat transfers from the wall to the product**

Diameter of milk bath 260mm

kinematics viscosity of milk at 51 °C ν<sub>m</sub> = 0.7968 × 10<sup>-6</sup> m<sup>2</sup> / s

Velocity of milk in bath we will mark as w<sub>m</sub> = 0.5ms<sup>-1</sup>

$$Re = \frac{0.5 \times 0.26}{0.7968 \times 10^{-6}}$$

$$Re = 163152.61$$

Re > 4000 movement of milk in the jacket is considered to be turbulent [9]

Prandtl number of waters in the exchanger with an average temperature of 51 °C is Pγ<sub>m</sub> = 5.547

In the boundary layer temperature of the milk would be 2 °C high than the temperature required for pasteurization [10]

Prandtl number of milk in the boundary at temperature of 67 °C is Pγ<sub>wall</sub> = 4.14

$$Nu = 0.03 \times 163152.61^{0.8} \times 5.547^{0.43} \times \left(\frac{5.547}{4.14}\right)^{0.25}$$

$$Nu = 997.48$$

Thermal conductivity of milk depends on temperature [10]. Thermal conductivity of water at average temperature of 51 °C λ<sub>m</sub> = 0.578 W/m.K

$$\alpha_2 = \frac{997.48 \times 0.578}{0.26}$$

$$\alpha_2 = 2217.48W / m^2 .K$$

**The heat transfer coefficient**

From equation (4.7)

$$K = 1268.8 \quad K = \frac{1}{\frac{1}{4108.26} + \frac{0.0015}{16} + \frac{1}{2217.48}}$$

**Heat transfer area**

$$F = \frac{Q}{K \times \Delta T} \quad (12)$$

$$F = \frac{1142.476}{1268.8 \times 35.198}$$

$$F = 0.02558m^2$$

Lateral surface area of the bath can be found by formula to find lateral surface of cylinder

$$s = 2 \cdot \pi \cdot \gamma \cdot h \quad (13)$$

$$s = 2 \times 3.14 \times 0.13 \times 0.208$$

$$s = 0.1698m^2$$

When comparing the heat transfer area F and lateral surface area S of the bath, we obtain that S>F consequently, heating milk in the bath will right selected heat exchanger is possible.

**Design of agitator**

**Power required for agitation**

Power required to operate an agitator depends on several factors such as the properties of the liquid, agitator type and size,

the tank or vessel size and speed of agitation [11]

$$P = N_p \times N^3 \times D_a^5 \times \rho \quad (14)$$

Where

P= Power required for agitation

$N_p$  =Power number

N= Speed of agitator

$D_a$  = Agitator diameter

$\rho$  = Density of liquid

In unbaffled vessel the relation between function power number  $N_p$  and Reynold number Re is given

$$NRe = \frac{D_a^2 \times N \times \rho}{\mu} \quad (15)$$

$$N_p = \frac{\alpha - \log_{10} NRe}{\beta} \quad (16)$$

Where

$N_{Fr}$  = Fraude number

$\mu$ =Dynamic viscosity

$\alpha$  and  $\beta$  are given as the function of diameter of the agitator (Table 3).

**Table 3:** Value of  $\alpha$  and  $\beta$  are given as the function of diameter of the agitator.

Diameter $D_a$	$D_a/D$	$\alpha$	$\beta$
10	0.3	1	4
15	0.33	1	4

$$N_{Fr} = \frac{N^2 \times D_a}{g} \quad (17)$$

Using the velocity of milk in the bath as  $W_m = 0.5m^{s^{-1}}$  then  $N \cong 1.5rps$  then

$$N_{Re} = 232438.02$$

$$N_{Fr} = \frac{0.183^2 \times 0.26}{9.81} = 8.876 \times 10^{-4}$$

$$m = \frac{1.0 - \log_{10} 232438.02}{4}$$

$$m = -1.09$$

From the graph above  $N_p = 1.02$

$$N_{p(corrected)} = N_p \times N_{Fr}^m \quad (18)$$

$$N_{p(corrected)} = 2162.93$$

$$P = 2162.3 \times 0.183^3 \times 0.26^5 \times 1027$$

$$P = 36.6$$

Considering 10% gland losses and 20% losses  $P=36.6W$ , so motor selection power  $P=50 W$

**Design of agitator shaft:** A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc., are mounted on it [12]. The agitator shaft was made from a standard AISI type 316 stainless steel that is Austenitic

$$\tau_{max} = 0.3S_{yt} \quad (19)$$

$$\tau_{max} = 0.3S_{yt} \quad (20)$$

For the selected material of Shaft S316

The ultimate tensile strength,  $S_{ut} = 515N/mm^2$

The Yield stress,  $S_{yt} = 515N/mm^2$

Therefore, the allowable shear stress ( $\tau_{max}$ ) is;

$$\tau_{max} = 0.3 \times 205 = 61.5N/mm^2$$

$$\tau_{max} = 0.3 \times 205 = 61.5N/mm^2$$

We take the smallest one,

$$\tau_{max} = 61.5N/mm^2$$

Agitator shaft will undergo only twisting moment

From the formula

$$P = \frac{2\pi NT}{60} \quad (21)$$

$$T = \frac{16.17}{2 \times \pi \times 0.183}$$

$$T = 14.06Nm$$

Also, from the formula

$$\frac{T}{J} = \frac{\tau_{max}}{r} \quad (22)$$

Where

T= twisting moment

J=polar moment

$$J = \frac{\pi d^4}{32} \quad (22)$$

r= radius of the shaft

d=diameter of the shaft

$$d^3 = \frac{16T}{\pi \tau_{max}}$$

$$= \frac{16 \times 14.06 \times 10^3}{\pi \times 61.5}$$

$$d = 10.53mm$$

**Design of DC power supply**

**Power supply data analysis**

From the block diagram of power supply, first consider transformer only (step down transformer). The transformer steps down AC voltage to DC voltage from 220-224VAC to 12VAC. The ratio of the number of turns on each coil called the turn's ratio, determine the ratio of the voltages.

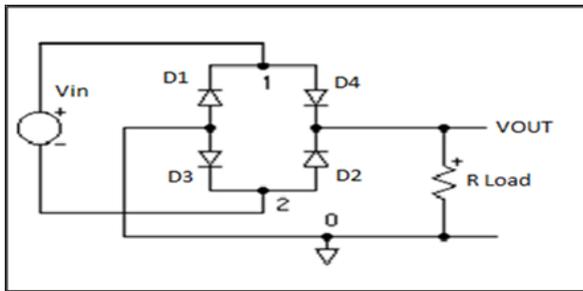
$$\frac{V_p}{V_s} = \frac{I_s}{I_v} = \frac{N_p}{N_s} \quad (23)$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{240}{12}$$

$$N_p : N_s = 20 : 1$$

**Rectifier**

Consider Figure 4,



**Figure 4:** Bridge rectifier circuit (Source: Author).

$$V_{peak} (sec) = 1.414 \times V_{rms} \quad (24)$$

$$= 1.414 \times 12 = 16.968V$$

$$V_{peak} (out) = V_{peak} (sec) - 1.4V \quad (25)$$

$$= 16.968V - 1.4V = 15.568V$$

$$PIV \text{ for each diode} = V_{peak} (out) + 0.7V \quad (26)$$

$$PIV = 15.568V + 0.7V = 16.968V$$

**Table 4:** Data gathered for microcontrollers.

Features	ATmega328p	ATmega32	Atmega8
Program memory	32KB	32KB	8KB
CPU Speed (MIPS/DMIPS)	20	16	16
Data EEPROM	1024B	1024B	512B
Timer	2x8bit, 1x16bit	2x8bit, 1x16bit	2x8bit, 1x16bit
Serial Communication	Receive (RX&transmit)	RX&TX, SPI	Pin2&3
Capture/Compare/PWM Peripherals	1 Input Capture, 1 CCP, 6PWM	1 Input Capture, 1 CCP, 4PWM	1 Input Capture, 1 CCP, 3PWM
General purpose I/O lines	32	44	32
analog input pins	6	8	8

**Filter**

$$V_{peak} (pri) = 1.414 \times V_{rms} = 1.414 \times 220V = 331V$$

$$V_{peak} (sec) = \left( \frac{N_s}{N_p} \right) \times V_{peak} (pri) = 0.05 \times 331V = 16.55V$$

Unfiltered dc (Voltage Peak rectified)

$$V_p (rect) = V_{peak} (sec) - 1.4V = 16.55 - 1.4 = 15.15V$$

Taking ripple factor of 3.97%, then capacitor will be.

$$C = \frac{1}{4f\gamma R \times \sqrt{3}} \quad (27)$$

Where, f=50Hz, γ = 0.0397, R= 3.6KΩ

$$C = \frac{1}{4 \times 50 \times 0.0397 \times 3.6 \times 10^3 \times \sqrt{3}}$$

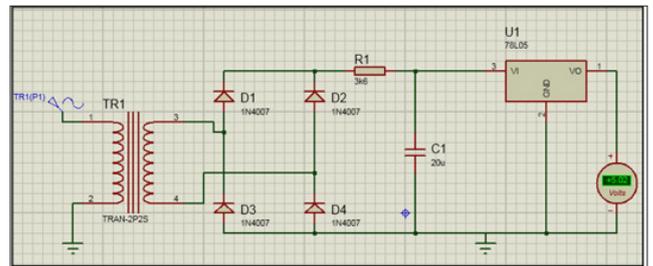
$$Capacitor = 20\mu F$$

Pure dc (filtered dc)

$$V_{dc} = \left( 1 - \frac{1}{2fRC} \right) \times V_{peak} (rect)$$

$$V_{dc} = \left( 1 - \frac{1}{2 \times 50 \times 3.6 \times 10^3 \times 2 \times 10^{-5}} \right) \times 15.15V = 12.18V \quad (28)$$

(Figure 5)



**Figure 5:** Power supply (Source: Author).

**Microcontroller selection**

The Table 4 shows data gathered for different microcontrollers. The ATmega32 and ATmega8 are rejected and ATmega328p is selected to be used with board because of the following features.

Operating Voltage Range (V)	1.8-5.5V	2.7-55.5V	2.7-55.5V
Max input current	40mA	40mA	40mA
SRAM	2048B	2048B	1024B
Temperature range (C)	-40-85	-40-85	-40p-85
Low Power	Yes		

- a. Low power device compared to other
- b. Wide voltage range compared to other two devices
- c. High operating speed
- d. Low cost

The reason for using atmega328p with Arduino boards is that,

- i) Inexpensive-Arduino boards are relatively inexpensive compared to other microcontroller platforms
- ii) Its programming language is simple (Arduino language)
- iii) No need of external programmer
- iv) Ease to use, as it has built in pins outs for providing you with 5v, 3.3v, ground, analog input, digital output, SPI, 12C etc.
- v) Cross-platform-The Arduino software runs on windows, Macintosh SX, and Linux operating systems. Most microcontroller system are limited to window

**The transistor switch design**

The transistor switch is used to drive the electromagnetic relay to switch on or off the appliances (electric heater). The type of the electromagnetic relay is 12V single pole double throw and the resistance of the coil 240Ω (Figure 6).

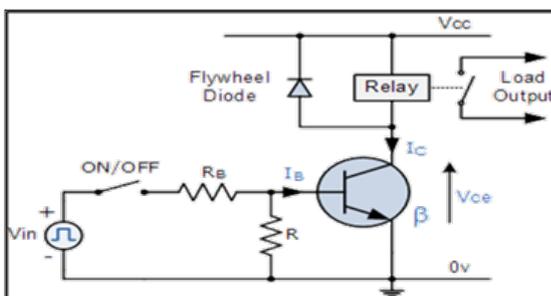


Figure 6: Relay switch.

**The transistor switch analysis**

The input voltage = 5V

The power supply source = 5V

The relay coil resistance = 240Ω/ 5V/F

The collector current of the transistor:

$$I_c = \frac{V_{cc}}{R_c} = \frac{5}{240} = 0.021A$$

The base current of the transistor:

$$I_b = \frac{I_c}{\beta} = \frac{0.021}{99} = 2.12 \times 10^{-4} A$$

The base resistance of the transistor:

$$R_b = \frac{V_c - V_{be}}{I_b} = \frac{5 - 0.7}{2.12 \times 10^{-4}} = 6.869k\Omega$$

The best choice of the transistor to use is 6.869kΩ.

**Designed circuit diagram**

(Figure 7).

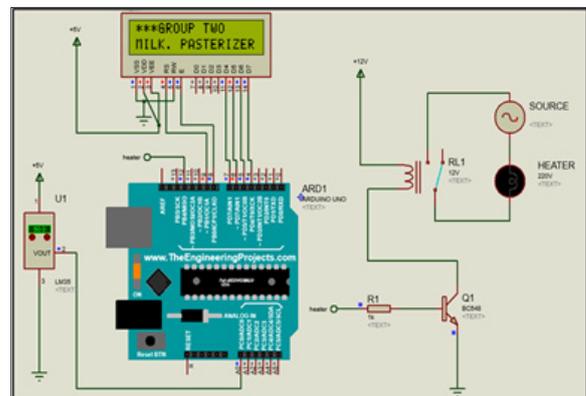


Figure 7: Designed circuit (Source: Researcher).

**Result and Discussion**

The results and discussion of the experiment carried out during evaluating the performance of Electrical water heating system assisted with heat exchanger to study its application for pasteurization of milk are presented in this chapter in order to fulfill the objective for which the project was undertaken. The data recorded during the course of investigation were analyzed suitably and presented as per the need. The results have been discussed, inferences are drawn and possible reason for them are given under the following subheadings along with the table and suitable illustrations.

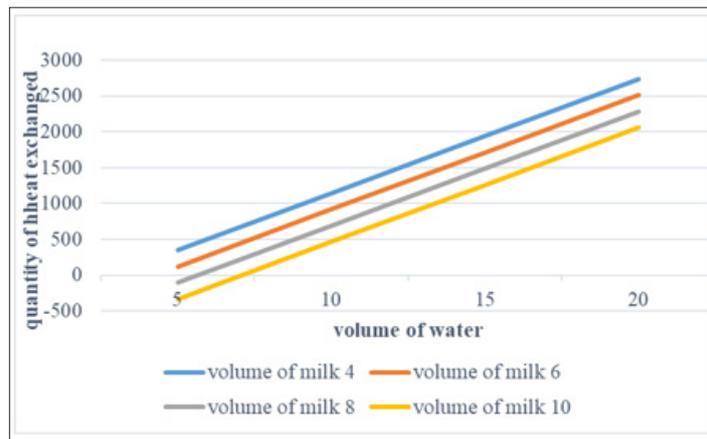
**Performance evaluation of heat exchanger**

The performance of heat exchanger was evaluated using electrical heated water. This experiment was carried out four times for each volume of milk at 4,6,8 and 10 liters and the volume of water in a jacket at 5, 10,15,20 liters. The parameter like rate of heat transfer on the basis of heat transfer from hot water in jacket to milk in milk tank and on the basis of time taken to reach the temperature were calculated during the course of experiment.

**Rate of heat transfer (Q):** Rate of heat transfer (Q) is the measure of the quantity of heat transferred from one medium to another. in order to evaluate heat required to rise the temperature of milk till pasteurization temperature, the heat rate from hot water to cold milk was calculated. Effect of effect of volume of hot water and volume of milk on the heat transfer rate (Q\_h). The values of

heat transfer from hot water ( $Q_h$ ) was calculated by putting the value of different variables like mass flow rate of hot water ( $M_h$ ), specific heat of hot water ( $C_{ph}$ ) and the difference between temperature of hot water, same data were calculated and is shown. Effect of effect of volume of hot water and volume of milk on the heat transfer rate ( $Q_h$ ) is shown in Figure 8. The values obtained for rate of heat transfer in the present study were in alignment with

the trend observed by Alawa et al. [13], Kee et al. [14] & Agrawal and Bhagoria [15] They also reported that when flow rate of hot water increased, the rate of heat transfer increased simultaneously. The statistical analysis was done to evaluate the effect of each independent variable (volume of hot) on the dependent variable (heat transfer rate from hot water) (Table 5).



**Figure 8:** Effect of volume of hot water and volume of milk on the heat transfer rate (Source Researcher).

**Table 5:** Rate of heat flow.

Volume of Water	Volume of Milk			
	4	6	8	10
5	346	120	-106.09	-332
10	1144	918	692	466
15	1942	1716	1490	1264
20	2740	2514	2288	2062

**Table 6:** Results of milk sample.

Milk Type	Temperature	Day					
		1	2	3	4	5	6
Raw Milk	Room Temperature 27 °C	Good	Bad	Bad	Bad	Bad	Bad
	Refrigerated 4 °C	Good	Good	Bad	Bad	Bad	Bad
Pasteurized Milk	Room Temperature 27 °C	Good	Good	Good	Bad	Bad	Bad
	Refrigerated 4 °C	Good	Good	Good	Good	Good	Bad

**Conclusion**

Despite the existence of pasteurization and its advocacy worldwide, most marketed milk in a developing country like Tanzania are sold raw by the locals [21-25]. Boiled milk ends up curdling which results into a loss of nutrients, so it is not beneficial to treat milk by this method. Therefore, adequate pasteurization of raw milk before consumption must be enforced, demands that it's readily affordable in terms of cost and maintenance which at the moment, plants of such small capacities for pasteurization of milk are rare. The mini plant was designed, fabricated (using stainless steel materials) and tested. The findings of the study were analyzed, and these conclusions were made [26-29]. The machine input capacity was 10 liters of milk after 30 minutes. The selected

**Quality of pasteurized milk**

The effect of electrical water heating system on quality of pasteurized milk was studied and compared with raw milk. The sample of raw and pasteurized milk were analyzed for parameter like number of days the milk sample can stay fresh. Nwobosi et al. [16] reported that the major disadvantage of spoilage organism in milk is that they easily multiply and cause unwanted effect. Analysis and comparison were made among two samples of cow milk and stored under the temperature of 4 °C as shown in the Table 6; [17-20].

pasteurization temperature and time were 65 °C and 30 minutes. The machine was able to increase shelf life of raw cow milk from 1 to 2 days when stored under room temperature and to 6 days when stored at temperature of 4 °C [30-34].

**Recommendation**

Based on the results obtained and the experience gained from the present study, some suggestions for future research [35-39]. Milk pasteurization could be improved and made even more feasible by optimizing the heating capacity of heating element to reduce heating time and hence the total pasteurization time. Providing some means to milk chilling immediate after pasteurization to be cold to temperature of 4 °C.

## References

- Food and agriculture Organization (FAO) of the United Nations Region office for Asia and the Pacific bangkok, 2014.
- Atia MF, Mostafa MM, Salam A, El Nano MA (2011) Solar energy utilization for milk pasteurization.
- O Conner CB (1994) Rural dairy technology training manual no 1. Addis Ababa: Internal livestock research Institute (ILRI), Kenya.
- Walstra PJ, Wouters TM, Geurts TJ (2006) Dairy science and technology. (2<sup>nd</sup> edn), CRC Press, Taylor and Francis Group, Florida, USA.
- Imele H, Kamage A, Mendi S (2000) Effect of pasteurization temperature on the total milk flora. *Animal Health and Production in Africa* 48(3): 177-181.
- Gbabo A, Gana IM, Dauda SM (2012) Effect of blade types on the blending efficiency and milk consistency of a grains drink processing machine. *Academic Research International* 2(3): 41-49.
- Fellows P (2000) Food processing technology: Principles and practice. (2<sup>nd</sup> edn), Woodhead Publishing Limited and CRC Press LLC, England and USA.
- Smith PG (2011) Introduction to food process engineering (2<sup>nd</sup> edn), Springer, Berlin, Germany.
- Singh RP, Heldman D (2013) Introduction to food engineering. (5<sup>th</sup> edn), Elsevier, Amsterdam, Netherlands.
- Ginzburg AS, Thunders MA, Krasovskaya GI (1980) Thermal and physical characteristics of food products. (2<sup>nd</sup> edn), Publishing House, Moscow, Russia.
- Asiri S (2012) Design and implementation of differential agitators to maximize agitating performance. *Saudi Arabia* 2(6): 98-112.
- Khurmi RS, Gupta JK (2005) Machine design. (5<sup>th</sup> edn), Eurasia Publishing House, New Delhi, India.
- Alawa BTL, Ohia IO (2013) Performance evaluation of heat exchanger in a polyethylene Plant. *International Journal of Engineering and Technology Innovation* 3(1): 49-57.
- Kee RJ, Almand B, Blasi J, Rosen B, Hartmann M, et al. (2011) The design, fabrication, and evaluation of a ceramic counter-flow microchannel heat exchanger. *Applied Thermal Engineering* 31(11-12): 2004-2012.
- Agrawal Y, Bhagoria JL (2011) Heat transfer characteristics of a copper-nickel multi tube with corrugated copper fins in a cross-flow heat exchanger. *Indian J Science and Technology* 4(11): 1532-1536.
- Nwobosi PNU, Isu NR, Agarry OO (2013) Influence of pasteurization and use of natural tropical preservatives on the quality attributes of tiger nut drink during storage. *International Journal of Food and Nutrition Science* 2(1): 27-31.
- Baldwin EE, Sokol GJ, Coffin LB (1998) Cyclic strain fatigue studies on AISI type 347 stainless steel. *Am Soc Test pp*. 17-25.
- Bhandari VB (2010) Design of machine elements. (3<sup>rd</sup> edn), McGraw Hill Education Publisher, USA.
- Cromie SJ (1991) Microbiological aspect of extended shelf-life products. *Australian Journal of Dairy Technol* 46(2): 101-104.
- De (2012) Outline of dairy technology. Oxford University Press, UK.
- Ryser ET, Marth EH (2007) Listeria, listeriosis and food safety. (3<sup>rd</sup> edn), CRC Press, Florida, USA.
- Goddik L, Sandra S (2002) Liquid milk product/pasteurized milk. *Encyclopedia of Dairy Science*. Academic press, Amsterdam, Netherlands 3: 1627-1632.
- Goksenli, Eryurek IB (2009) Failure analysis of a mixing shaft. *Engineering failure analysis*.
- Grant IR, Ball HJ, Rowe MT (1999) Effect of higher pasteurization temperature and longer holding times at 72 °C, on the inactivation of mycobacterium paratuberculosis in milk. *Letter in applied microbiology* 28(6): 461-465.
- Haq IU, Israr K, Salman M, Marry Y, Ali I, et al. (2014) Effect of heat treatment on sensory characteristics and shelf-life of skimmed milk. *African Journal of Food Science* 8(2): 75-79.
- Holsinger VH, Rajkowski KT, Stabel JR (1997) Milk pasteurisation and safety: A brief history and update. *Rev Sci Tech Off Int Epiz* 16(2): 441-451.
- Mukhametgaliyev FN, Avkhadiyev FN, Gaynutdinov IG (2011) Specialized reference book of agro-industrial complex industry. Publishing house of the Kazan University, Kazan, Russia.
- Kutz M (2007) Handbook of farm dairy and food machinery.
- Santos MV, Fonseca LFL (2000) Milk quality and mastitis control. lemon Editorial, Sao Paul, Brazil, p. 175.
- Saxena M, Rai P (2013) Microbiological and chemical analysis of raw, pasteurized and UHT milk during preservation in India. *International Journal of Chem Tech Research* 5(6): 2804-2809.
- Wilson GS (1943) The pasteurization of milk. *British Medical Journal* 1(4286): 261-262.
- Shah RR, Sekulic DP (2003) Fundamentals of heat exchanger design. John Wiley and Sons, New Jersey, USA.
- Sharma KS, Sehgal N, Kumar A (2003) Dry reagent strips for testing milk pasteurization. *Swiss Society of Food Science and Technology* 36(6): 567-571.
- Srairi MT, Moudnib J, Rahho L, Hamama A (2006) How do milk condition affect the hygienic quality of raw milk, case study from Moroccan dairy farms. *Livestock Research for Rural Development*.
- (2010) United Republic of Tanzania, Economic Survey, Tanzania.
- (2017) WAFP. Pasteurizer Operator.
- Winarso D, Herawati, Foekh B (2011) The study of temperature effect and length of pasteurization heating on milk quality. *Journal of agriculture and Food Technology* 1(8): 137-144.
- Duffie JA, Beckman W (2006) Solar engineering of thermal processes. (3<sup>rd</sup> edn), John Wiley and Sons, New York, NY.
- Inox E (2007) The welding of stainless. (2<sup>nd</sup> edn), Materials and Applications Series. Luxembourg.

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