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RE-DESIGING AND FABRICATION OF THE CONTACT AREA OF A SOLAR MILK PASTEURIZER

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Abstract

Despite the existence of pasteurization and its advocacy worldwide, most marketed milk in a developing country like Nigeria are sold raw by the locals. It costs hundreds of millions of Naira to set up a conventional pasteurizing plant in Nigeria. Boiled milk ends up curdling which results in to a loss of nutrients, so it is not beneficial to treat milk by this method. This paper hence presents the re-designing and fabrication of the contact area of a solar milk pasteurizer

Introduction

The application of engineering to improve on the efficient use of energy has made heat transfer an integral part of engineering worth studying. The qualities of consumables and human life style 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.

There are different types of heat transfer devices and a heat exchanger is one of it. Heat exchangers are thermal devices that transfer or exchange heat from one fluid stream to one or more others (Chris and Naser, 2009). In liquid food industries, heat exchangers for many years have become an essential component in the process line (Bako, 2015).

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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. Barttlett (1996) opined that since a possible presence of pathogenic organisms requires that food be heated above a certain temperature even though, too high a temperature will affect the product quality and increase in production cost. The nature of fluid within a system also affects pressure drop and heat transfer, as an example, temperature control is affected by an abrupt fluid composition change.

In the food and dairy industry, heat exchangers play a pivotal role. The heat exchanger designed to use solar energy is the solar collector (Klemens, *et al*, (2003). The application of solar collector in milk processing involves liquid milk movement and it is an important operation which cannot be overlooked. The flowability of milk within a system is determined by its density and viscosity. The physics of these properties go a long way in the determination of developing a heat exchanger. Since in the food and dairy industry consumables are produced, paramount importance is placed on the materials and the thermal treatments of these foods. Through thermal bacterial destruction kinematics studies, the time needed for a specific fraction of pathogenic organism destruction has been examined (Bako, 2015). Success can only be considered achieved in the thermal destruction process in the food and dairy industries only when the number of viable organisms considered safe for human consumption is less than that present in it before the heat treatment process was embarked upon.

Milk and its products are fundamental in human nutrition (Atia *et al*, 2011). 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 (Atia *et*

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al, 2011). Milk is considered safe for consumption when it contains 5×10^6 bacterial per ml (O' Conner, 1994). Milk products and their cost are determined by an effective design of a heat treatment plant.

The consumption of contaminated liquids and other liquid foods (milk inclusive) has been attributed to the cause of about 80% of infectious diseases including diarrhoea, typhoid, cholera in developing countries (Onyango *et al*, 2009). 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 Organisation (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 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 other to make surface water and dairy products safe for human consumption, there is therefore need to have a design which will heat treat these raw consumables thus, pasteurization comes in.

The consumption of un-pastured dairy product has been found to be a channel for the transmission of zoonotic diseases from animals to man. Heating milk to a temperature below its boiling point over a specific period of time is hampered by the epileptic power supply in our country. Recommendation by the Nigerian Food and Drug Administration and Control (NAFDAC) and her united state counterpart the Centre for Disease Control (CDC) has it that only pasteurized milk be consumed as raw milk contains harmful bacteria such as Listeria Salmonella and even E.coli 0157:47 which may cause life threatening illness. Efforts to make

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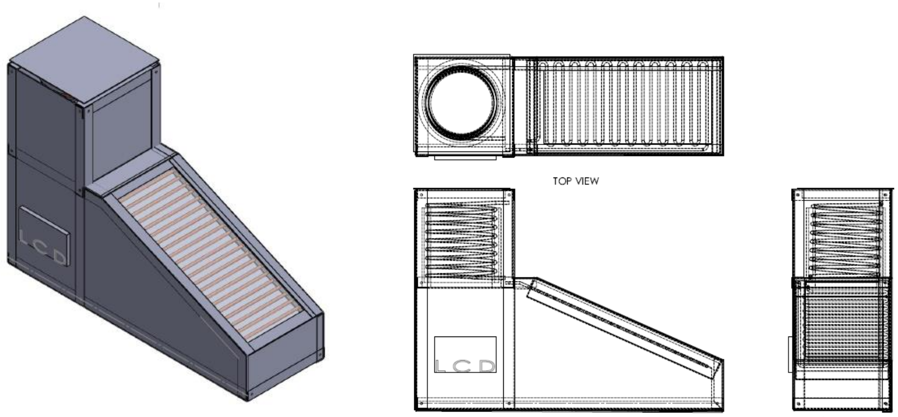
quality milk readily available and affordable through indigenous research and technology to safeguard the health condition of the citizens (Bako, 2015). The available solar pasteurizers use the immersion method where the milk vat is completely immersed in a water jacket. Therefore, this paper seeks to redesign the area of contact with the milk vat where the heat exchange process (pasteurization) takes place for improved performance.

Design/Fabrication Processing

Some of the components that makes up the solar milk pasturiser are , flat plate collectors, tubes and absorber plates, glazing materials, thermal insulators, rivet pins. Figure 1 below gives some of the working drawing of the designs



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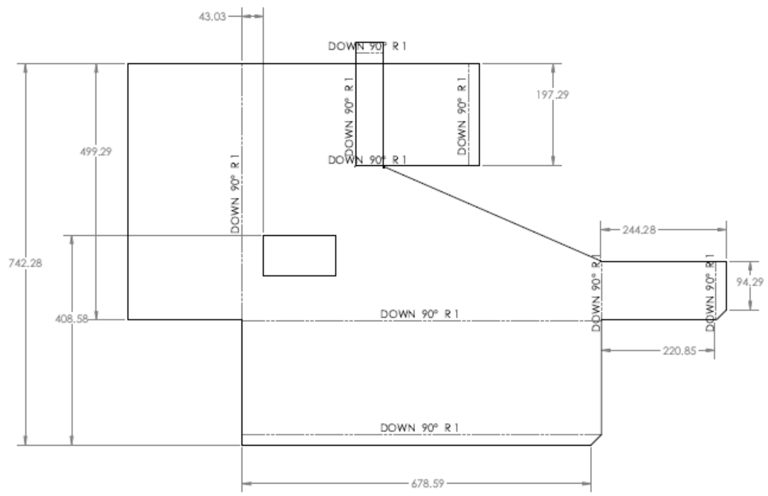

Figure 1: working drawing of the solar pasturiser

The supporting frame was fabricated using mild steel, rectangular pipes ($20\text{mm} \times 40\text{mm}$) of 4mm thickness same used in fabrication in (Moveh Samuel, 2016) . The process involved cutting the rectangular mild steel pipes into different pieces which represents the dimensions of the frame as shown in the working drawing. Hack saw, measuring tapes and electric arc wielding machines were used to produce the supporting frame.

The absorber is a 1600mm $\times$ 400mm $\times$ 5.6 mm Aluminium sheet painted black on which the zigzag copper pipes containing the working fluid (water) will pass. The black coating absorbs almost all solar radiation that falls on it. And the space underneath the absorber is filled with insulation material (fibre glass) that retains the heat of the absorber. This layer was made 5cm thick.

The re-design milk vat was fabricated from a 1.5mm thick food grade stainless steel with an extension of the zigzag copper pipes from the absorber taken round the vat to provide for the heat exchanging. This vat was maintained at a height of .26mm from the collector to allow for the flow of the working fluid at maximum flow rate by convection from the collector.

Material/Method

In the selection of materials for the re-design of the solar pasteuriser as seen in figure 1, certain factors were considered. Factors like availability, cost and health implication.

From the working drawing it can be seen that Rivet pins were used as fasteners in joining the different components of the solar pasteurisers together. The flat plate solar collector was selected because it is relatively simple and its characteristics are known. It is the easiest and least expensive to fabricate, install, and maintain. Moreover, it is capable of using both the diffuse and the direct or beam solar radiation. For residential and commercial use, flat plate collectors can produce heat at sufficiently high temperatures to heat domestic hot water, in buildings; they also can operate a cooling unit, particularly if the incident sunlight is increased by the use of a reflector. Flat plate collectors easily attain temperatures of 40 to 80ºC ((Soja, Enebe, & Samuel, 2019, Rhushi *et al*, 2011).

Also from the drawings, glass was chosen as the glazing material. This is because glass is capable of transmitting solar energy. From the standpoint of the utilisation of solar energy, the important desirable characteristics of a glazing material are low reflectance, *(ρ*), low absorptance, *(a*), and high transmittance, *(t)*. For a glass, reflectance and absorptance is very low and the transmissivity is high. The choice of glass for the glazing is to admit as much solar radiation as possible and to reduce the upward loss of heat to the lowest attainable value. Glass has been the principal material used to glaze solar collectors because it has the highly desirable property of transmitting as much as 90% of the incoming short-wave radiation (solar), while virtually none of the long wave radiation emitted by the flat plate can escape outward by transmission, as can be seen in (Rhushi *et al,* 2010, Victor & Moveh, 2017).

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In the design , the primary function of the absorber plate and tubes in the collector is to absorb as much as possible the radiation reaching their surfaces through the glazing, to lose as little heat as possible upward to the atmosphere and downward through the back of the container, and to transfer the retained heat to the circulating fluid. Aluminum sheet was selected as the absorber plate for this design because it has the properties mentioned above. Its durability, ease of handling, its availability and relatively low cost are other major factors considered in its selection. Copper tube was selected and preferred over any other metal for water passages because of its high conductivity and compatibility with water. Absorber plates are usually given a surface coating (black is commonly paint was used) that increases the fraction of available solar radiation absorbed by the plate (absorptance a). The matte black paints, for which a = 0.92 to 0.98 were selected as in (Duffie and Beckman, 2013). Finally Fiber glass-wool and hard foam material were selected for the thermal insulation of the flat plate, storage tank and connecting pipes. These insulation materials are known to be dimensionally and chemically stable at high temperatures, and resistant to weathering and dampness from condensation as stated by (Rhushi *et al.* 2011).

Conclusion

Despite the existence of pasteurization and its advocacy worldwide, most marketed milk in a developing country like Nigeria are sold raw by the locals. It costs hundreds of millions of Naira to set up a conventional pasteurizing plant in Nigeria. Boiled milk ends up curdling which results in to 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 cost of constructing milk pasteurizers and its subsequent space economy has been a major constraint to engineers. Thus, this re-design and fabrication of a simple small scale solar milk pasteurizer is a step in the right direction to save the lives of the citizenry. Hence the idea of this paper is justified.

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