Automation of Traditional Butter and Ghee Production

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Abstract: - Traditionally, Jordanian butter has always been made from yogurt. When a sufficient amount of sheep milk has been collected, it is fermented then churned by mechanical shaking until butter granules are formed. In making butter from yogurt, the objective of churning is to extract the maximum amount of fat by transferring the emulsion from oil in water to water in oil. The liquid that remains after extracting butter - buttermilk - is used to produce a type of dry yogurt called Jameed, a local dairy product in Jordan. This traditional method of churning is time-consuming, perhaps taking more than two hours. Observations made of traditional butter-making by smallholders have indicated that the process should be improved by increasing the efficiency of fat extraction from the yogurt and reducing the processing time, thereby improving the economic return. Toward this end, this research has achieved tow objectives, the first is designing one unit to process and automate the butter churning process, and the second one is improving the churning process efficiency. The ultimate goal of this research is achieved by building a one machine for the local organic butter, Fat and Jameed manufacturing. A device is developed that rapidly and consistently agitates milk to churn butter. This device has passed through several phases of development over the last years. Many experiments have been done to design and select churn parameters like rotor velocity, churn temperature. Many experiments also have been done to select the best sensors that can be used to control the whole process which includes heating, cooling, fermentation, and churning.

Key-Words: - Dairy mechanization, Butter Churn, Process automation, Ghee Production

1 Introduction

The electrical activity of active nerve cells in the brain produces currents spreading through the head. These currents reach the scalp surface, and the resulting voltage differences on the scalp can be recorded as the electroencephalogram (EEG). EEG reflect brain electrical activity.

Local butter churning process is used to make butter by shaking up the yogurt. Agitation of yogurt is done by mechanical motion, which disrupts fat globules and change emulsion from oil in water to water in oil. Butter grains are formed by breaking down the milk fat globules membranes (Walstra, 1999). Churning causes these grains to fuse with each other and form butter. The liquid that is left out without fat is called buttermilk. Because of the technological development butter churns have varied over time. First, local butter churns were made of animal materials like animal skins. Later other materials like wood, metal or glass were used as containers to churn butter. Local churning process is still a manual process although there were some attempts in the world to do that, as in (Funahashi, 2008), (Gonfa, 2001), (Avramis, 2003), (Aljaafreh, 2011). In manual churning process, human being makes the decision when to end the churning process, when a satisfied quantity or quality of fat or butter milk is collected. This research has two major objectives, the first is to design a machine to process and automate the butter churning and fermentation process (Aljaafreh, 2015), and the second one is to improve the churning process efficiency. The ultimate goal of this research is building a machine for the local dairy products that form one of the fastest growing segments in the livestock products. In achieving this goal several sensors, and control system need to be applied as in (Van Vliet, 1980) and (Aljaafreh, 2014). In churning process, sheep milk is processed to produce buttermilk, fat, and Jameed. Dairy producers can benefit from this research by applying the developed technique and manufacturing process. Local butter, fat and Jameed are all almost homemade products. Consumers and food makers who use local butter, fat and Jameed always demand to have their foods of higher standards and better quality. Nutritional value, health benefit and safety are essentials to food quality. Food safety is a very basic right of people. One of the main goals of this research is to ensure a better and consistent dairy product quality. To the best of our knowledge this is the first try of automating such kind of manufacturing process (Aljaafreh, 2011).

The traditional process of Jameed and butter production from sheep milk in Jordan is initiative and mostly done by primitive equipment. This make the process need a hard work for a long time. The sanitation are poor so the products cannot be graded as safe food for the consumers. The microbiological quality of milk are poor due to bad hygiene during milking, no effective milk cooling and low standard at plant cleaning.

The process starts by milk collection, as in Fig. 1.

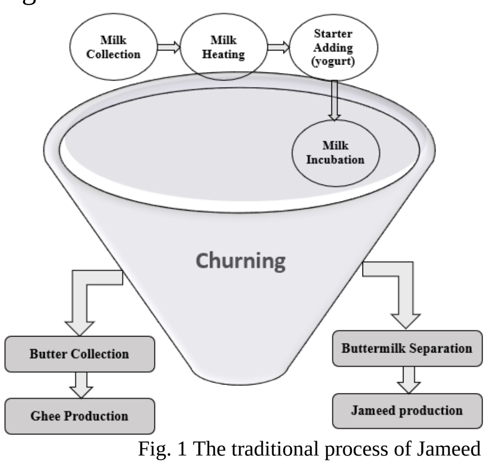

Fig. 1 The traditional process of Jameed and butter production from sheep milk

It is mostly done by using plastic or aluminum containers with very low standards of cleaning. The farmers heats the milk to fermentation temperature by direct gas fire. The next step is adding the starter (yogurt) to the heated milk for fermentation process. After that the milk is incubated at worm temperature for at least 3 hours. Normal blanket are used to keep the warm condition through fermentation process. Starter bacteria convert lactose to lactic acid which convert the liquid milk to a jelly-like yogurt. Then the product is cooled by adding chilled water and cubic of ice to start churning. The next step is churning. Most of the time, churning is done by using a plastic churn which have low hygiene standards. Churning takes about one hour to make the butter fat float on the surface. The next step is butter collection. Farmers collects the butter fat by their naked hands and transferred to a very chilled water to make balls of butter to be stored in mostly plastic drums. The butter milk which is left after the churning transferred to aluminum vat to be heated without agitation by direct gas fire to allow the whey to be separated from the butter milk. Heated butter milk filled in a cloth bags with adding table salt and kept for 3 days to remove the whey as much as possible. After that the dehydrated buttermilk is emptied in plastic containers to mix it by hand and try to make balls of Jameed and left outside to be dried. Then, the stored butter are transferred to aluminum vat to be cooked by direct gas fire after adding at least 10 kinds of herbs to overcome the rancidity taste which is developed due to unappropriated processing. The heat will evaporate the water and concentrate the fat in the ghee.

Plastic and aluminum are used in all processing equipment, both of them are not suitable for food production. Plastic migrate carcinogenic compounds to the food and aluminum can lead to a Parkinson's disease. Not cooling the milk in milk collection stage reduces the quality of milk due to the growth of microorganisms and that will lead to acidity development and production of many materials which can badly effect human health and production process (Farah, 1989). Enzymes activity accelerated due to high storage temperature leads to fat degradation which produces rancidity in the final products especially the ghee. While protein degradation gives rise to unwanted taste in the Jameed. Milk pasteurization is not done by the farmer. This may lead to a very dangerous situation for the farmer and the costumers due to the transference at milk-borne disease from the animal to the human as shown table 1. Many other microorganisms can contaminate the milk from the farmer, worker and the environment which can effect badly human health and the process.

Table 1 Causative organism of diseases from the animal to the human

Disease	Causative Organism
Mastitus	Staphylococcus aureus streptococcus uberis streptococcus agalactiae Escherichia coli listeria monocytogenes
Johne's disease	Mycobacterium avium Subsp paratuberculosis
Tuberculosis	Mycobacterium bovis Mycobacterium tuberculosis
Brucellosis	Brucella abortus Brucella melitensis

The only way to stop the bacterial hazard is milk pasteurization.

There are no control equipment for the heating and cooling of the milk and the products, fermentation process and the acidity development of the milk and churning processes.

Also direct gas fire for heating can rise coked flavor and brown color to the final products. Adding chilled water and ices to the products for cooling increase the possibility of contamination.

2 Materials and Methods

The ultimate goal of this research is the automation of the process of Jameed and butter production and improve the microbiological quality of the products to get a safe and very hygienic products. Automation will produce a high quality products with excellent flavors and a high solubility characteristic for the Jameed and butter. To achieve the above objectives and overcome all production problems of the traditional process we designed a special process tank which can be do all the steps aseptically will special characteristics.

The tank is made from a grade food stainless steel and have no interaction with the products. It has two jacketed layer and have the ability to heat and cool the product electrically. It also contains a special agitator which can move in different speeds. A low speed for agitating the milk and the product during heating and cooling. A High speed for churning the yogurt. The agitator has round shape impeller with a diameter of 15 cm with a very sharp teeth as shown in Fig. 2.

Fig. 2 Shear impeller

The tank can be made with different capacity between 50 kg to 300kg of milk. It can finish the churning process in 50 min at a speed of 1400 round/s and a temperature of 14 c. Churning recovery (yield) is a measure of how much of the fat in the yogurt has converted to butter. It is expressed in terms of the fat remaining in the buttermilk as a percentage of the total fat in the yogurt. For example a churning recovery of a 0.5 means that a 0.5% of the yogurt has remained in the buttermilk and 99.5% has been tuned into butter. Churning yield is considered acceptable if the value is less than 0.7 (Papademas, 2010), (Jones, 2018), and (Griffiths,2010). The yield in our tank is as in Table 2. Fat measurement has been done by a very precise method called Majonnier which depends on weight of extracted fat. These results show that churning process considered acceptable.

Table 2 Churning recovery (yield)

Batch No.	% fat in the yogurt	% fat in the buttermilk
1	6.8	0.37
2	6.9	0.46
3	7.1	0.51
4	7.2	0.49
5	6.9	0.52

Heating of the milk and the yogurt inside the tank done through the jacket gradually with the slow agitation which keep the products with no cooked flavor. The tank is equipped by many sensors to control and monitor the heating processes, fermentation processes and churning Process

Jameed manufacturing process, which has been followed by our work, is as follows:

1- The raw sheep milk stored in the processing tank and cooled down to 4 C. Cold storage of milk will keep it with high quality, preventing the growth of microorganisms and stop the activity of enzymes.

2- Milk pasteurized at 90 c for 5 minutes. This high heat treatment bring about a number of chemical, microbiological and physical changes:

a- Kills contaminating and competitive organisms

b- Production of growth factors by breakdown of milk proteins.

c- Heat-induced interaction between casein and denatured whey protein to create body and texture for the yogurt. Denaturation of whey proteins increases their water binding capacity.

3- By using temperature sensor, the tank can stop heating when temperature rises to 90 c. The embedded system will keep the milk at that temperature for 5 minutes a holding time for pasteurization process. Then the milk cooled down inside the tank to 43 c as an optimum temperature for the growth of the starter organisms.

4- Starter culture at level of 2% added to the milk, the starter contains the following bacteria:

a- Lactobacillus delbrueckii Subsp. Bulgaricus

b- Streptococcus thermophilus

Starter bacteria converts lactose to lactic acid (pH reduced to 4.5-4.6). Starter bacteria will develop flavor compounds especially acetaldehyde. Association growth between lactobacilli and Streptococcus increases rate of acid and flavor production (Tamime, 2009), (Skeie, 2007).

5- Produced yogurt cooled down to 14 c for churning process.

6- Churning process will make a foam of large protein bubbles due to agitation of the yogurt. Being surface active, the membranes of the fat globules are drawn toward the air/water interface and the fat globules are concentrated in the foam. When agitation continues, the bubbles become smaller as the protein gives off water, making the foam more compact and thereby applying pressure on the globules. This causes a certain proportion of the liquid fat to be pressed out of the fat globules and cause some of the membranes to disintegrate. The liquid fat, which also contain fat crystals, spreads out in a thin layer on the surface of the bubbles and on the fat globules. As the bubbles become increasingly dense, more liquid fat is passed out and the foam is soon so unstable that is collapses. The fat globules coagulate into grains of butter, at first, these are invisible to the naked eye. But they grow progressively larger as working continues (Robinson, 2005), (Frye, 2008), (Tamime, 2009), (White, 2008).

7- The floated butter granules are collected by sterilized (by hot water) sieve made of stainless steel and kept at low temperature store to be manufactured for a ghee through 1the evaporation of water by heating to achieve a fat percentage of 95%.

8- One of the conductivity, density and viscosity can be used as a sensor to follow the progress of the churning process.

9- The buttermilk which been left inside the tank after removing the butter heated up to 55 c with no agitation to help in whey separation.

10- The buttermilk will be packed in a cloth bags to remove whey. Filling the cloth bag done through a butterfly valve build up at the bottom of the tank.

Cloth bags will be left under pressure for at least three days under pressure to remove most of the whey and the final product (Jameed) will be shaped to round-shape to be dried environmentally.

Local butter, Fat and JAMEED are all homemade products that are still produced manually. The production process has many steps and stages that need to control. There are problems of the manually homemade products. The first is the quality of the produced Jameed is inconsistent. It varies according to the process parameters. Each family process it in a different way. The second is the safety. Many of the families don't pasteurize milk which makes it unsafe for producers as well as for customers. The third is the process efficiency in terms of power and time. In this research the three problems are tackled and solved by designing, building, and testing a high-tech local butter churn for automating the local butter churning process and come up with a high quality and safe products that can be commercialized. Also the local churning process efficiency is improved, less power, less cost, less time, more butter, and better and consistent dairy product quality.

In this research a one tank is designed to automate all processing steps. All the processing steps are done in a sterilized, closed tank, leaving no chance for any contamination. The process is done with very little work because there is no need to transfer the products and no need to use gas fire for heating and chilled water for cooling. The ability of the tank to cool the raw milk will keep the quality of milk with very high standard. The ability of the tank to pasteurize the milk will keep the product safe, hygiene with acceptable flavors. The sensors of the tank will control all heating and cooling, fermentation, and churning processes.

Automation is using technologies to operate machines and systems without human intervention to achieve higher operation performance than manual operation (Aljaafreh, 2017). Sensors, actuators and controller are the three main components of industrial automation system.

This research main goal is to select the proper sensors to automate churning and fermentation process. To automate the churning process, a sensor is needed to end the churning process when the sufficient amount of butter is collected. We assumed that the conductivity, density, and viscosity changes according to the process. This assumption is based on the fact that when the butter is extracted from the yogurt the conductivity increases since butter has a very low conductivity. Buttermilk (which is called Makheedh or Shaneena in Jordan) has a higher density than yogurt since butter is lighter than water. This is also applied for viscosity. To prove the concept we did many churning experiments measuring conductivity, density, and viscosity before and after the churning process.

3 Results and Discussions

A churn is designed and built as in Fig. 3 to perform many experiments measuring conductivity, density, and viscosity before and after the churning process while controlling the temperature and speed of rotation.

Fig. 3 a 200-Liter Butter churn

It consists of a 200 liter stainless tank with a drain outlet. 1 HP Single Phase Electric Motor 240V 1400 RPM. A refrigeration unit is selected and attached to the tank to control the churning temperature. A one phase inverter is used to control the angular speed of the motor. The tank has holes for all kind of sensors. A shear impeller is designed as in Fig. 2. This first prototype as in Fig. 1 enabled us to conduct experiments while controlling the temperature as well as the angular speed of the impeller. Another 4-liter churn is designed as in Fig. 4 to perform quick experiments to save milk.

Fig. 4 small churn for samples

3.1 Experiment 1

The first goal of this stage is to optimize the churning process to minimize the churning time. The main objective of this experimental study was to know the start temperature of the yogurt for the churn process (the temperature of the yogurt before churning as in Table 3).

We churn on five different temperatures. We have found that the best temperature is 12 Cº as it is shown in Table 3. In experiment 1 as in Table 3, churning is done on different yogurt temperature. We recorded the churning time which is the time it took to ripen the yogurt. Churning efficiency in terms of the amount of collected butter is shown in Table 4.

Table 3 Start and end temperature of yoghurt churning process

Exp#	Yoghurt temperature before churning C º	Time of churning in minutes	Butter milk temperature at the end of churning C º	notes
1	6	120	11	Fat does not crystallize unless adding hot water to rise temperature up to 12 ºC
	6	125	11	
	6	130	12	
2	8	125	12	
	8	130	13	
	8	124	13	
3	10	90	14	Temp. reaches up to 14 ºC at the end of churning
	10	100	14	
	10	96	14	
4	12	50	16	Temp. reaches up to 18 ºC at the end of churning
	12	52	18	
	12	51	18	
5	14	50	19	Butter was very soft and very difficult to be collected. Temp. reaches up to 20 ºC at the end of churning

Table 4 Churning efficiency in terms of the amount of collected butter

Yoghurt amount in kg	Milk fat %	Butter weight (kg) with 80% fat	Milk total fat weight kg	Butter total fat	Churning efficiency %
100	7.8	8	7.8	6.4	82
100	7.6	7.5	7.6	6	78.9

Table 5 Conductivity is measured by electrodeless conductivity stick meter 5JI

Exp#	Conductivity before churning (µs)	Conductivity after churning (µs)
1	7450	9230
2	7140	9110
3	7240	9190
4	7220	9110

Table 6 Viscosity is measured with simple method by running 200 ml of yoghurt at 20 ºc through a 250 ml separating funnel and measure the time in seconds it takes to pass through the nozzle of the separating funnel

Exp #	Viscosity before churning (second)	Viscosity after Churning (second)
1	35	18
2	41	20
3	38	18
4	40	19

3.2 Experiment 2

The main goal of the experiments conducted in this research is to choose which parameter can be used to start and end churn process automatically among conductivity, viscosity and density. The conductivity, density, and viscosity of the milk under process were read before and after the churn process. Results are shown in Tables 5, 6, 7.

Table 7 Density was measured by weighting 25 ml of product

Exp#	Density before churning (g/ml)	Density after churning (g/ml)
1	0.99	1.11
2	1.02	1.13
3	1.01	1.11
4	1.03	1.13

Conductivity is measured by electrodeless conductivity stick meter 5JI as in Table 5. Viscosity is measured with simple method by running 200 ml of yogurt at 20 ºc through a 250 ml separating funnel and measure the time it takes to pass through the nozzle of the separating funnel as in Table 6. Density was measured by weighting 25 ml of product as in Table 7. From table 7, several remarks can be drawn. Firstly, density increases after churning since the density of the butter milk is greater than the density of yogurt since it losses the fat which is lighter than water. Secondly, ripening can be recognized by checking conductivity and time as it is clear in Table 8 and Table 9. Finally, conductivity, density, or viscosity can be used to start and end churn process automatically.

Table 8 Conductivity and temperature through yogurt churning

Time from the beginning of churning process (Minutes)	Temperature (cº)	Conductivity (µs)
0	13.9	7960
15	15.9	8020
35	16.1	9000
45	16.1	11740

Table 9 Conductivity of buttermilk at the end of churning process

Churn number for 100 kg of yogurt	Butter Milk Conductivity (µs)
1	12000
2	12000
3	12000
4	14000

3.3 Experiment 3

Since the goal of this stage is to optimize the churning process to minimize the churning time, the main objective of this experimental study was to know the relation of the impeller speed to the churning time.

Table 10 The relation between the impeller angular speed and the Churning time in minutes

Exp #	Impeller angular speed rpm	Churning time in minutes
1	1000	110
2	1000	120
3	1000	118
4	1500	55
5	1500	59
6	1500	58
7	2000	35
8	2000	32
9	2000	35

We churn on three different impeller speeds as in Table 10. We have found that the churning time decreases as the impeller angular speed increases. Electrical available churn faces many problems. First and for most is the lack of control sensors to start and end fermentation and churning process. Available electrical churns need to be optimized in some variables. Firstly, rotation speed of the agitator. The amount of fat in butter and churning time are directly proportional to the speed of rotation. Secondly, the churning temperature of yogurt or cream. As the temperature of the yogurt goes lower, it helps to have larger amount of butter. However it increases the churning time. Electrical available churn rises the temperature of yogurt during the agitation process.

The first factor that effects on the amount of butter and agitation time is the proportion of fat in yogurt (or cream).The higher the percentage of fat in the yogurt is the higher is the proportion of fat in the resulting butter. The second factor is the degree of cleanliness of yogurt. The third factor is the amount of water added during the churning process.

Water used in this process lowers the percentage of fat in resulting butter. The last factor is the process time (fermentation and churning).

Ultrasonic sensors can provide a rapid, accurate, inexpensive, simple and non-destructive method to on-line asses and monitor the properties of food during process operations. Ultrasonic is not an off-the-shelf technology. Thus it needs to be developed and scaled up for each application. I have already evaluated the use of ultrasonic measurements to characterize yogurt fermentation process by correlating acoustic proprieties (velocity and impedance) and fermentation process characteristics. The research showed the correlation between fermentation time and relative acoustic impedance as well as acoustic velocity. Ultrasonic measurements can be used to characterize the butter churning process since I have already found the relation between acoustic proprieties (velocity and impedance) and the butter churning process. This will lead to design a unit to process and automate the butter churning process using ultrasonic sensor which will improve the fermentation and churning process efficiency as well as the quality and safety of dairy products. I also did many experiments to determine the optimal process parameters like rotation speed and churning temperature.

Consumers and food makers who use local butter, fat and Jameed always demand to have their foods of higher standards and better quality. The food quality is an essential matter in addition to nutritional value, health benefit and safety. There is consensus that food safety is a very basic right of people, various effort have been devoted by all sectors to ensure that the goal of safer food for all would be attained. One of these research goals is to ensure better and consistent dairy product quality. The result of this is an automatic butter churn that can ferment and churn butter in one tank which is controlled by cheap sensors. Dairy producers can benefit from this research by buying our new technique and manufacturing process, since our technique will be the first in the region since local butter, fat and Jameed are all almost homemade products. Small sheep farmers, dairy manufacturer, and food makers may benefit from the result of this research.

5 Conclusions

Dairy products form one of the fastest growing segments in the livestock products in Jordan. In this research, the churning and fermentation process is automated for the local organic butter, fat and Jameed manufacturing. This study is based on an extensive study of user requirements. We did field visits to all Dairy factories in Al-karak governorate like Ader, Msherfh and University of Mutah Faculty in agriculture faculty. We also met with the president of the sheep breeders association and a group of breeders. We discussed the problems related to the process of milk churning. There was a consensus on the urgent need for a station that could do pasteurization, fermentation and churning automatically without human interference and so as to obtain a product of good quality and high safety.

Thus we investigated the market to find out the types of sensors that can be used in process automation. A system design is proposed in this research to automate a manufacturing process for the production of the local organic butter, fat and

Jameed. Automation is based on fluid conductivity, temperature and time. To the best of our knowledge we are the first who think of automating such kind of manufacturing process.

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