Milk Flash Pasteurization by the Microwave and Study its Chemical, Microbiological and Thermo Physical Characteristics

Asaad R Saeed Al-Hilphy* and Haider I Ali
Food Science Department, College of Agriculture, Basrah University, Basrah, Iraq

Abstract
The study included pasteurization of cow’s milk by the Flash Pasteurization method and using temperature of 100°C for a period of 0.01 seconds. The chemical tests were measured and included determination of moisture, fat, lactose, ash and protein. The microbiological tests included estimating of the total number of microbes, bacteria of the colon (E. coli) and surviving fraction. Thermo physical properties were calculated for milk and included specific heat, viscosity, thermal conductivity and density during the different temperatures. TBA and free fatty acids were measured. Productivity of the device reached to 60 liters/hour and heating rate is 22.22°C/min. The results showed that the microbiological characteristics were improved after the flash pasteurization process by reducing the total number of microbial, and absence of Coliform bacteria in pasteurized milk. The pasteurization value, specific heat and thermal conductivity of the milk were increased with increasing time of heating, while viscosity and density of the milk were decreased with increasing temperature. Moisture, acidity and pH were decreased after the flash pasteurization process. Ash and carbohydrates have been increased. Fat and protein were not affected with pasteurization process. Results also showed the absence of alkaline phosphatase in pasteurized milk. TBA and free fatty acids were significantly (p<0.05) reduced by using microwave flash pasteurization.

Keywords: Milk pasteurization; Thermo physical properties; Pasteurization value

Introduction
One of the most important heat treatment transactions in dairy plants are pasteurization and sterilization. There are general bases for pasteurization can be summarized in the following two points: the first is health and the eradication of pathological microorganisms in milk, pathogenic organisms and the elimination of 95 to 99% of the number of bacteria present in the milk, as well as the process of pasteurization causes total elimination of yeasts and molds gets through exposure of milk for different temperatures for specified time periods. The second point is increasing milk storage time as free of the microbes is increases the storage and safety of microbial damage. The Food and Health Bureau of United States the US Food and Drug Administration introduced certain measures in the pasteurization of milk and its products and these gauges consisted of temperatures as milk or products and the time required is 62.8°C for 30 minutes, 71.6°C for 15 seconds, 88.4°C 0.1s, 95.6°C for 0.05 seconds and 100°C for 0.01 seconds. Milk heating at 100°C for 0.01 seconds is called flash pasteurization.

As pointed out by Ryan et al. [1] that there are many types of microorganisms in milk can be observed which effect its quality as well as its negative impact on consumer health and safety. As which Louis pasteur in 1860 was found a method called later the process of pasteurization, which being capable of eradicating most unsatisfactory microbes. Many researchers developed thermal treatments, however, these methods have many disadvantages in terms of storage age of pasteurized milk through rancidity, flavor and dramatic growth of Microbes [2].

The manufacturing process use microwave heating as non-traditional technologies. Relatively modern microwave device is a radioactive energy electromagnetic waves and frequency in the range from 300 MHZ to 300 GHz. It has set the International Telecommunication Union (ITU) frequency range of microwave heating is 2,101 MHz for household and industry. Water, proteins and carbohydrates within the polar molecules that coalesce in the range of electric microwave frequency for this movement style. Reciprocating movement for this scope and billions of times per second lead to friction and thus heat generation also produces heat from the movement of electrically charged ions within food. Heating up food by microwave is highly dependent on the physical properties of water due to Intermolecular hydrogen bonds and facilitate movement and energy exchange with the photons which facilitates water heating microwaves to the extent of his oscillations as a type of heating better than the traditional heating [3].

Microwave pasteurization gives less damaged product comparison with traditional thermal treatment, this is due to the short treatment time and thermal radiation [4,5]. Sieber et al. [5], Lau et al. [6], Wang et al. [7], and Albert et al. [8], founds that the loss of free amino acids was less than the traditional way. Sieber et al. [5] stated that pasteurized milk by microwave has not harmful effects on health. John et al. used a microwave for pasteurization of milk in HTST at 72°C for 15 seconds as a quick method, also they found a reduction in total bacteria, psychotropic bacteria counts, E. coli and alkaline phosphates in comparison with pasteurized milk in fast way. The current study aimed to milk pasteurizing at a temperature of 100°C for 0.01 seconds in a microwave, to study the susceptibility of the device on the inhibition of microorganisms in pasteurized milk and its thermo physical properties as well as milk antioxidant.

Materials and Methods
Cow’s milk was provided from agricultural researches station,
Agriculture College-Basrah University. A microwave apparatus was used to milk pasteurization, type 956 Kenwood mw, Korean origin, its power 1000 W. Temperature measured by digital temperature measurement device, type XMTD Korean origin provided with thermocouple Cu-constantan type. The quantity of pasteurized milk in every experiment is 1 L.

Pasteurization value was calculated from the following equation [9]:

\[ P_j = \int_{T_{55}}^{T_{55}} 10^{(T-100)/z} \, dt \]  \hspace{1cm} (1)

Were \( P_j \) is total Pasteurization value (minute), T is a milk temperature (°C), \( T_{55} \) is the initial pasteurization time, \( T_{55} \) is the final Pasteurization time when \( T \) is less than 55°C.

Inactivation of microorganisms (surviving fraction) is calculated from equation (2) [10]:

\[ \log \left( \frac{N_j}{N_{0j}} \right) = -\frac{t}{D_j} \]  \hspace{1cm} (2)

\[ D_j = D_{0j} 10^{\frac{T_j-2}{Z}} \]  \hspace{1cm} (3)

Where \( \frac{N_j}{N_{0j}} \) is the required reduction for various microorganisms population, \( D_j \) and \( D_{0j} \) are the decimal reduction times at temperature \( T \) and \( T_j \) respectively, \( T_{0} \) is a reference temperature usually 100°C and \( Z \) is the thermal resistance factor in °C, \( t \) is the time (min).

Decimal reduction time \( D_j \) is the time required for 90% reduction (one log cycle) of population is given by the equation (4) [11]:

\[ D_j = \frac{T_j - T_i}{\log N_j - \log N_{0j}} \]  \hspace{1cm} (4)

Where \( N_j \) and \( N_{0j} \) are the initial and final numbers of microorganism after time of heating t at the given temperature. \( (T_j-T_i) \) is the variation of time.

Thermal resistance factor \( Z_j \) is the temperature rise required to reduce the decimal reduction time by 90% (one log cycle) is given by the equation (5):

\[ Z_j = \frac{T_j - T_i}{\log D_j - \log D_{0j}} \]  \hspace{1cm} (5)

\( (T_j-T_i) \) is the variation of temperature.

The productivity is a total milk quantity which output from apparatus at specified time. It’s unite is L/hr.

Heating rate can be estimated from the equation: [9]

\[ H_r = \frac{T}{t} \]  \hspace{1cm} (6)

Thermo physical properties for milk:

Specific heat can be obtained by the following equation 7 [12]

\[ C_p = 1.68T + 3864.2 \]  \hspace{1cm} (7)

The viscosity of milk is given by equation (8) [12]

\[ \mu = (-0.00445T + 0.947) \times 10^{-3} \]  \hspace{1cm} (8)

Thermal conductivity is calculating according to equation (9) [12]

\[ \lambda = 0.00133T + 0.539911 \]  \hspace{1cm} (9)

In which the milk density is calculated by equation (10) [12]

\[ \rho = 1033.7 - 0.2308T - 0.00246T^2 \]  \hspace{1cm} (10)

Nutrient Agar media was attended by dissolving 28 g in one liter of distilled water and then sterilized by autoclave at 121°C for 15 minutes.

MacConkey Agar medium was attended by dissolve 51.5 g in 1 liter of distilled water and then sterilized by autoclave at 121°C for 15 minutes and used in the calculation of the number of coliform.

Chemical Testing of pasteurized and unpasteurized liquid milk were included the following:

Moisture was determined by the mentioned manner in the A.O.A.C. [13].

Protein was determined according to Kjeldahl [14].

Fat has been estimated by [14].

Lactose sugar was determined by measurement of the difference among components

Ash is determined according to [14]. Milk samples were examined for total plate counts and total coliform according to APHA [15]. The milk samples were serially diluted with peptone water (0.1%) and appropriate dilutions plated on media using the pour plate method.

The presence and number of total bacterial count were evaluated on nutrient agar. The plates were incubated at 37°C for 24-48 h.

For the enumeration of total coliform the MacConkey Agar was used, the plates were incubated at 37°C for 24-48h.

Phosphatase enzyme has been detected in the raw and pasteurized milk according to enzymatic method by using kit that tested by Egyptian company for biotechnology.

Statistical analysis

All results are the mean of three replicates. Data were analyzed by ANOVA within a completely randomized design. LSD tests were used for mean discrimination (5% level of probability, using the SPSS) [16].

Results and Discussion

Milk heating curve by microwave and cooling are given in Figure 1. As shown in this figure that temperature is significantly (p<0.05) increased with increasing time. The required time to up rise milk temperature from 20 to 100°C is 4.2 min (heating stage). In the holding
stage milk is stayed for 0.01 min. at 100°C. The third stage is cooling stage that need to 32.3 min.

Heating at 100°C for 0.01 second caused an increasing in pasteurization speed, decrease in time and destroyed all microbes. This method highly speeds in food industries.

The main aim of heating process is the contribution in food storage and decrease the level of food bacteria. The heating process divides into three stages, heat, holding and cooling.

The effect of pasteurization value appear when temperature exceeded 55°C that pasteurization analyses depend on heating and holding stages only (Halleux, 2005). Values of pasteurization are also depends basically on D value. Where D represent the time required for a temperature of 100°C to kill 90% of bacteria. This time was 0.95 in current study (Figure 2).

Result of microbiologic evaluation of pasteurized milk samples on 100°C (Table 1) showed a decrease in the number of bacteria \((23 \times 10^1)\). This indicates the effect of heating treatment on microbes viability. In addition result of the tests done on pasteurized milk a negative present of \(E.\ coli\) of all test samples. These results are with full agreement with those of Soler et al. [17]. The result shown in Figure 3 indicated a decrease in all bacteria percentages with the increase in time of heating in microwaves. The percent was 0.32% with the heating at 100°C for 4.64 second. Alkaline phosphates disappeared in pasteurized milk.

Table 2 showed the effect of temperature on the specific heat, viscosity and thermal conductivity and density. Specific heat and thermal conductivity increased with increasing temperature. Specific heat is defined as the energy required to raise mass unit temperature or it may be known as the amount of heat lost or gained per weight unit until the product reach the required thermal degree without changing the state. Specific heat influenced by the moisture content of the product, temperature and pressure. It increases as moisture level increase. It is also higher at static pressure rather than constant size. At all application of food engineering industry, specific heat is used at constant pressure [18]. Heat transfer coefficient of any product as numerical unit is the average temperature transfer through diameter unit of the product when the difference in temperature at the edges, that transfer coefficients of most food with high moisture contents close to that of water [19]. It is one of the important properties which determine heat transfer through foods during production processes and moisture content has great effect on food heat transfer [20].

Viscosity and density decreased with increasing temperature. The negative relation between density and temperature is clear in milk rather than water. The reason behind that is protein and fat in milk, while lactose has very less role [21]. Viscosity is the resistance of one layer of the liquid against the other; it is also mean as the ratio of the resistance to the cut and cutting speed. Viscosity is a quality factor of many foods. Its value only consider as a quality factor but as a method of product control [22]. Reached the productivity of the device 80 l/h. The speed of the heating 22.22°C/min.

Table 3 shows the percentage of the chemical composition of milk cows. If moisture is lower in the sample using pasteurized temperature 100°C compared to the control sample may be attributed to the evaporation of water in milk using high temperature results showed that as a slight rise in the \(pH\) of the sample being scalded due to remove \(CO_2\) during heating which reduces the acidity results agreed with Zygooura et al. [23].

As shown in Figure 4 the total microbial count (Log (CFU/ml)) in microwave flash pasteurized milk is significantly \((p<0.05)\) less than control treatments (without microwave flash milk pasteurization) at 5 and 25°C. This result was less than the minimum Iraqi standard specification, which stated that the total count bacteria in pasteurized milk of good quality are 10000 CFU/ml (4 log CFU/ml) and 50000 CFU/ml (4.698 log CFU/ml) with acceptable quality milk.

Figure 5 Shows TBA values vs. storage time at 5 and 25°C with

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**Table 1**: Microorganisms and Alkaline phosphates in the milk before and after microwave flash pasteurization.

| Temperature (°C) | Microorganism | CFU/ml (Log) before | CFU/ml (Log) after |
|------------------|---------------|---------------------|-------------------|
| 10               | E. coli       | 9                   | 0                 |
| 20               | E. coli       | 9                   | 0                 |
| 30               | E. coli       | 9                   | 0                 |
| 40               | E. coli       | 9                   | 0                 |
| 50               | E. coli       | 9                   | 0                 |
| 60               | E. coli       | 9                   | 0                 |

**Table 2**: Microorganisms and Alkaline phosphates in the milk before and after microwave flash pasteurization.

| Temperature (°C) | Specific heat (J/kg.K) | Viscosity (Pa.s) | Thermal conductivity (W/m.K) | Density (kg/m³) |
|------------------|------------------------|-----------------|-----------------------------|-----------------|
| 10               | 3881                   | 0.0000925       | 0.553211                    | 1031.142        |
| 20               | 3879.8                 | 0.000858        | 0.565511                    | 1028.1          |
| 30               | 3914.6                 | 0.008135        | 0.579811                    | 1024.562        |
| 40               | 3931.4                 | 0.00769         | 0.593111                    | 1020.532        |
| 50               | 3948.2                 | 0.007245        | 0.606411                    | 1016.01         |
| 60               | 3965                   | 0.00688         | 0.619711                    | 1010.996        |
| 70               | 3981.8                 | 0.006355        | 0.633011                    | 1005.49         |
| 80               | 3996.6                 | 0.00591         | 0.648311                    | 999.492         |
| 90               | 4015.4                 | 0.005465        | 0.659611                    | 993.002         |
| 100              | 4032.2                 | 0.00502         | 0.672911                    | 986.02          |
and without microwave flash milk pasteurization. TBA values in the microwave flash pasteurized milk are significantly (p<0.05) less than control treatments (without microwave flash milk pasteurization) at 5 and 25°C. TBA values were significantly (p<0.05) increased with increased storage time at 5 and 25°C, these increasing may be due to increasing air spaces into milk granules. In addition cow milk has high fat ratio. This result agreed with Al-Sifir et al. [24].

Free fatty acids vs. storage time with and without microwave flash milk pasteurization are showed in Figure 6. Free fatty acids in the

| Moisture content | Fat | Protein | Ash | Lactose | Acidity | pH |
|------------------|-----|---------|-----|---------|---------|----|
| **Before flash pasteurization** | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a |
| **After flash pasteurization** | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a | 1.66 ± 86.8a |

Table 3: Chemical composition (%), acidity (%) and pH for raw and microwave flash pasteurized milk.
microwave flash pasteurized milk are significantly (p<0.05) less than control treatments (without microwave flash milk pasteurization) at 5 and 25°C and at all storage times. This reducing because microwave energy is penetrates milk at all its sides. These results are agreement with Semt et al. [25].

Conclusions

In conclusion, the microwave has been successively in milk pasteurization at 100°C for 0.01 sec. (flash pasteurization) and gave a good quality of pasteurized milk. TBA and free fatty acids were significantly reduced by using microwave milk flash pasteurization. Total count of bacteria, TBA and free fatty acids are increased with increasing storage time. The time required to up rise milk temperature to 100°C is 4 min. and stayed at 100°C for 0.01 min. Chemical composition was no significantly by using microwave flash pasteurization. Pasteurization value was increased with increasing heating time.

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