

Study considering the microwave pasteurization of the raw milk used for yogurt production

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Abstract

The aim of this research was to assess how the variation of the microwave power and of the exposure time during different pasteurization regimes of raw milk affects the obtained yogurt. The novelty of the study was the use of microwaved milk in the production of probiotic yogurt. The obtained products were analyzed considering their organoleptic, physical and chemical characteristics. The most appreciated yogurt was yogurt B, obtained by heating the raw milk in the microwave oven set on the 80 % (640 W) power, for 240 s (4 minutes), which received the highest overall average of the organoleptic assessment, of 4.768. Also, yogurt B had the lowest value for acidity, 85°T which can be justified by the fact that the fat content decreased least of all, of only 9.77 %. This percentage of fat reduction can be explained by a reduced lipolysis, because this yogurt had the lowest acidity value in spite of the highest decrease suffered by lactose of 30.8 %, generating the highest quantity of lactic acid during the thermostatisation process. Also, the fact that the lipases were most affected by this regime of pasteurization can explain the smallest average grade obtained by this yogurt for smell.

Keywords: functional foods; unconventional pasteurization; organoleptic, physical and chemical analysis

1. Introduction

Microwaves are defined as a part of the electromagnetic waves which have a frequency range between 300 MHz and 300 GHz (G. RULEA [1]). Microwaves technique has been applied in many food industry processes such as drying, tempering, blanching, cooking, pasteurization, sterilization and baking, due to its considerable advantages over the conventional heating methods, especially regarding the energy efficiency (P. Puligundla & al. [2]). Microwave heating of food is generated by the microwave energy conversion into heat caused by the water molecules friction based on the fluctuation of the electromagnetic field, this technique being characterized by a volumetric heating (N. N. Potter & al. [3], J. ZHU & al. [4]).

Microwave technique has also been used to heat milk products generating improved sensorial characteristics compared to conventional heating. Generally, yoghurt is consumed not only because of its high nutritive value and improved organoleptic properties, but also due to its health-promoting effects, especially its probiotic effect (C. Siefarth & al. [5], E. J. Llorent-Martínez & al. [6]).

Probiotic dairy products are functional products, obtained from milk after the inoculation with specific cultures of lactic acid bacteria and thermostatisation (L. YÉPEZ & al. [7], É. Csutak [8]). Between probiotic bacteria very important are *Lactobacillus acidophilus* and bifidobacteria. *Lb. acidophilus* of human origin shows antibacterial activity against a significant number of Gram-negative and Gram-positive pathogens (*Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella typhimurium*, *Shigella flexneri*, *Escherichia coli*, *Klebsiella pneumoniae*, *Bacillus cereus*, *Pseudomonas aeruginosa*) (G. M. COSTIN & al.

[9]). Also, *Lb. acidophilus* does not inhibit the activity of lactobacilli and bifidobacteria (M. H. Coconnier & al. [10]). Thus, the probiotics have a diverse range of clinical and immunological capacities (N. MAFTEI ARON & al. [11]).

There are many studies on the microwave treatment of milk (A. M. Constantin & al. [12] H. Zhang & al. [13], E. Valero & al. [14], P. A. FINOT & al. [15], R. A. Heddleson & al. [16], A. Medrano & al. [17], S. N. AKTAS & al. [18]) and other kinds of food (C. SEVERINI & al. [19], S. O. KESKIN & al. [20], O. J. WILLIAMS & al. [21], M. E. Lucchesi & al. [22], C. Beaudry & al. [23], N. Seyhun & al. [24], M. N. Ramesh & al. [25], G. SUMNU [26], T. N. Tulasidas & al. [27]), but there is very little information about the use of this milk in the production of dairy products (M. Villamiel & al. [28]), mainly yogurt. Thus, the purpose of the study was to investigate how the variation of the microwave power and of the exposure time during different high pasteurization regimes (recommended for the yogurt production) of milk affects the organoleptic and the physical-chemical characteristics of the obtained yogurt.

2. Materials and Methods

High pasteurization of raw milk was made using SILVA MWG-E 5080 microwave oven, with 800 W electrical power. Milk used for the experiments was obtained from a local farm. The analyses were made on samples of 250 ml milk, using plastic graduated unclosed vessels. Milk was subjected to several tests in order to establish the optimal high pasteurization regimen. The accomplishment of this type of pasteurization was controlled by the albumin test and by the method using potassium iodide and starch.

Thus, there were established 3 regimens of high pasteurization for the raw milk used to produce 3 types of probiotic yogurt which were shown in table 1.

Table 1. Raw milk pasteurization regimens

Yogurt type	Microwave oven power, W	Exposure time, s	Achieved temperature of the sample, °C
Yogurt A	800 (100 % power)	180	90
Yogurt B	640 (80 % power)	240	90
Yogurt C	480 (60 % power)	270	92

During all the pasteurization processes it was used raw milk with an initial temperature of 27°C. Raw milk and pasteurized milk were analyzed in order to determine: chlorides quantity (direct titration method), lactose (potassium ferricyanide method), fat, nonfat dry matter, density and proteins (using EKOMILK M ultrasonic analyzer). After the pasteurization process, the milk was used to obtain the 3 types of yogurt by inoculation with cultures specific to probiotic yogurt.

Organoleptic assessments were conducted on the yogurts, using a specific punctuation scale (C. BANU & al. [29]), by a 15 member team who respected the afferent organoleptic rules. Also, the yogurt was analyzed to determine its: acidity, through the titrimetric method; dry substance using an oven at $102 \pm 2^\circ\text{C}$; fat content by butyrometric method and lactose, by the spectrophotometric method, using a T60 UVVIS SPECTROPHOTOMETER at 490 wave length. Based on the obtained results there were developed mathematical models to describe

the correlation between microwave power, time and different indicators values of the yogurts using STATGRAPHICS program.

3. Results and discussion

Raw and pasteurized milk analyses results and discussion

The integrity of the raw milk was investigated and demonstrated by the values obtained for the analyzed parameters, so this milk can be further processed. Also, the pasteurized milk was analyzed to see how the microwave treatment affected its characteristics (Table 2).

Table 2. Raw milk and microwaved milk physical-chemical characteristics values

Milk Type	Values for the measured parameters					
	Fat (%)	Nonfat dry matter (%)	Density (areometric degrees, °A)	NaCl (g ‰)	Protein (%)	Lactose (%)
RM	3.76±0.02	9.07±0.04	29.6±0.2	1.63±0.05	3.56±0.06	7.22±0.03
M100%	3.91±0.05	9.26±0.03	30.4±0.1	1.87±0.03	3.64±0.04	4.51±0.01 ^b
M80%	3.90±0.03	9.16±0.06	30.0±0.1	1.90±0.02	3.59±0.02	4.77±0.04 ^b
M60%	3.85±0.04	9.14±0.05	29.9±0.3	2.20±0.04 ^a	3.59±0.03	4.64±0.02 ^b

Values are expressed as the mean ± standard deviation of three determinations, a(0.01<P≤0.05); b(0.001<P≤0.01); c(P≤0.001). RM - raw milk; M100% - milk microwaved at 100 % power; M80% - milk microwaved at 80 % power; M60% - milk microwaved at 60 % power.

From the above table, there can be seen that the raw milk pasteurized in the microwave oven suffered a concentration phenomenon dependent on the oven electrical power and on the duration of exposure. Thus, the highest density value and nonfat solids value were obtained when the milk was microwaved at 100 % oven power, fact that can be explained by the specialty literature which reveals that the microwave treatment can affect the vitamin content, especially vitamin E, C and B9 (R. SIEBER & al. [30]).

The fat content followed the same variation trend with the nonfat solids and density, having the highest value of 3.91 % reached at 100 % oven power. According to the speciality literature the milk fat exposed to microwave action usually suffers these processes: autooxidation and trans fatty acids isomers formation (A. M. AL-Rowaily [31], S. M. Herzallah & al. [32]).

Also, the protein content suffered the same variation with the fat content and considering the data literature this can be caused by: the exposure to the surface of the whey protein sulfhydryl groups usually buried within the core of the protein structure, protein sulfhydryl groups which may be also formed because of hydrolysis or β-elimination of disulfide bonds and which participate in subsequent oxidative reactions and ultimately contribute to the production of reactive oxygen species which generate lipids oxidation; some insignificant changes of the amino acids and by the fact that the milk proteins can be involved in the Maillard reaction together with lactose (T. FLOREA [33], M. Villamiel & al. [28]). It seems that the lactose is the most affected component of milk due to microwave exposure, because its value decreased from 7.22 % in the raw milk to 4.51 % at 100 % oven power exposure,

most likely being isomerized to lactulose in the Maillard reaction first stage (P. Resmini & al. [34]).

Probiotic yogurt analyses results and discussion

Follow-up the organoleptic analysis, each yogurt was noted with marks from 0 to 5 for the sequentes characteristics: aspect, color, consistency, smell and taste. Afterwards, the average of the grades taken by each feature of the 3 types of yogurt was calculated and also an overall average of the organoleptic assessment for each yogurt (Table 3).

Table 3. Average values of the yogurts organoleptic characteristics

Yogurt type	Average of the grades for the yogurts organoleptic characteristics					Overall average of the analysis
	Aspect	Color	Consistency	Smell	Taste	
Yogurt A	4.86	4.8	4.46	4.73	4.73	4.716
Yogurt B	4.86	4.86	4.73	4.66	4.73	4.768
Yogurt C	4.53	4.93	4.53	4.73	4.46	4.636

The way in which the organoleptic characteristics of the 3 types of yogurt were appreciated can be observed in the following graphic (Figure 1).

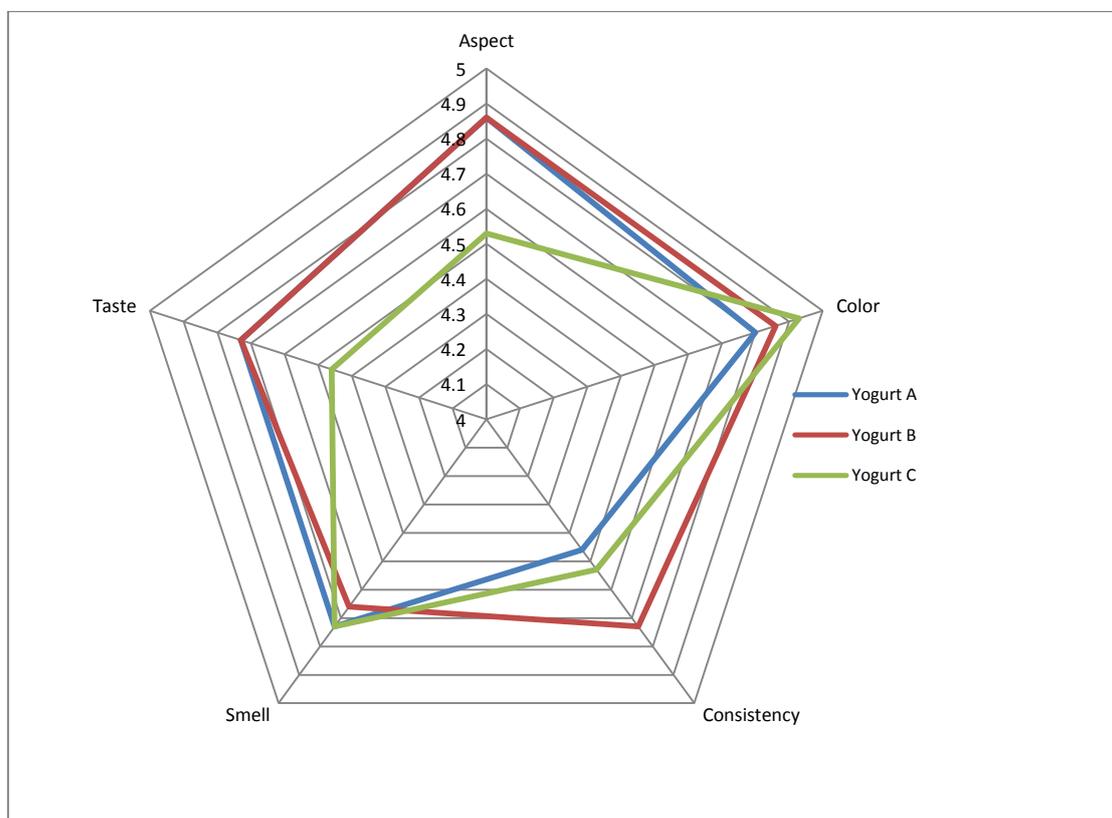


Figure 1. The results of the organoleptic analysis for yogurt A, yogurt B and yogurt C

From the above graphic, there can be seen that the most appreciated yogurt, having an overall average of 4.768, was yogurt B, obtained by heating the milk in the microwave oven set on the 80 % (640 W) power for 240 s (4 minutes), followed by yogurt A, produced from milk pasteurized at 100 % power of the oven and the last one, yogurt C resulting from milk pasteurized at 60 % microwave power. Yogurt B was most appreciated in terms of aspect, consistency and taste.

The variation of the yogurts physical-chemical characteristics depending on the pasteurization regimens used for the raw milk is shown in Table 4.

Table 4. Average values of the physical - chemical characteristics of the probiotic yogurts

Yogurt type	Average for 3 values of the measured parameters			
	Fat (%)	Dry substance (%)	Acidity (°T)	Lactose (%)
Yogurt A	3.6	13.61	87	3.18
Yogurt B	3.5	12.99	85	3.30
Yogurt C	3.4	14.23	93	3.22

The correlation between microwave power (x), time (y) and different characteristics of the yogurts (z) can be described by the equations resulting from the following graphics (Figures 2-5).

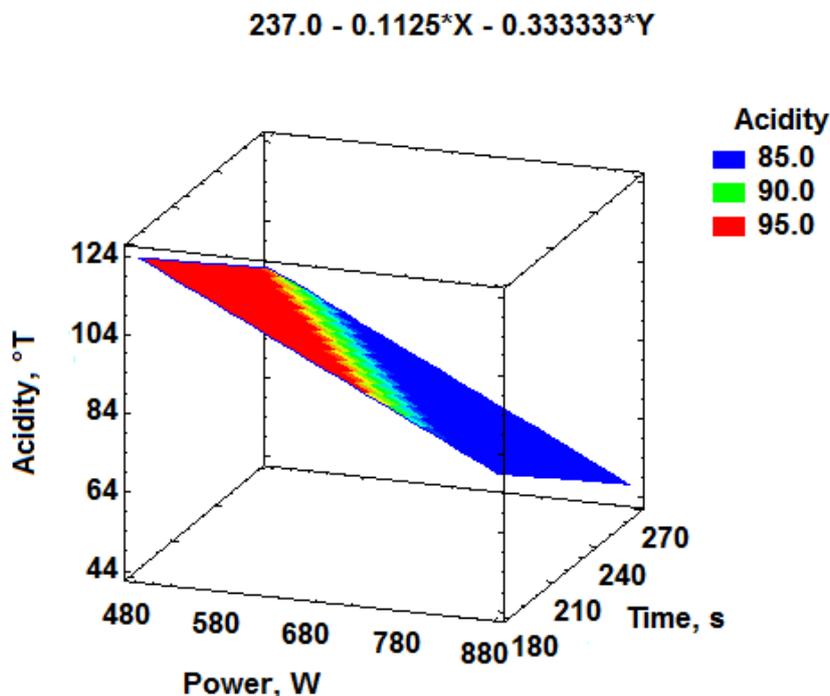


Figure 2. Yogurts acidity values depending on pasteurization regimens

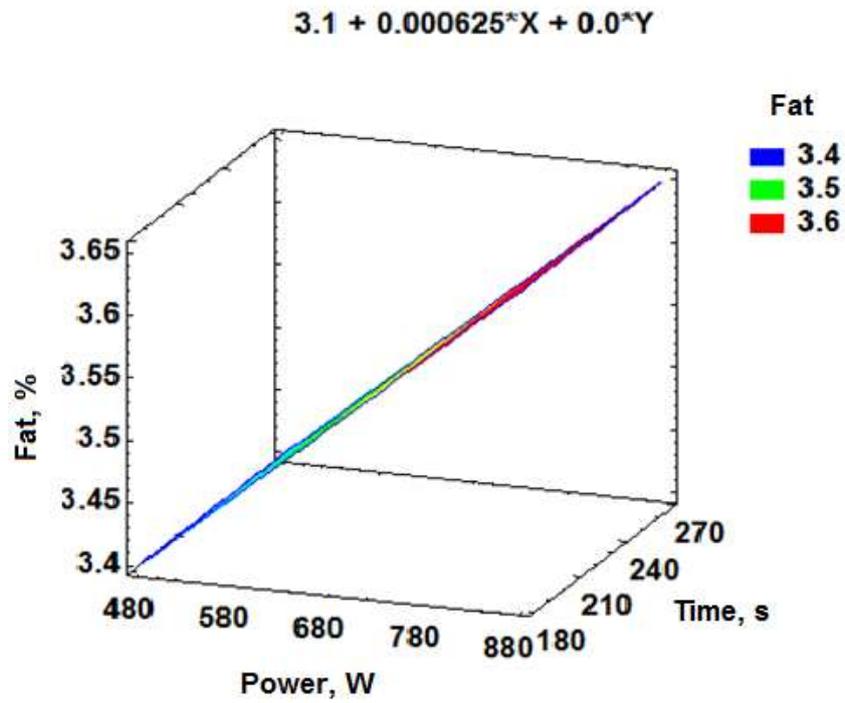


Figure 3. Yogurts fat values depending on pasteurization regimens

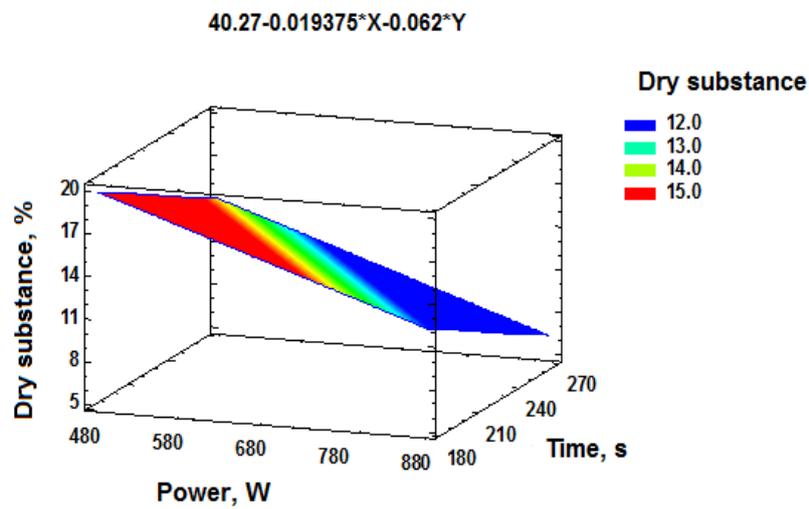


Figure 4. Yogurts dry substance values depending on pasteurization regimens

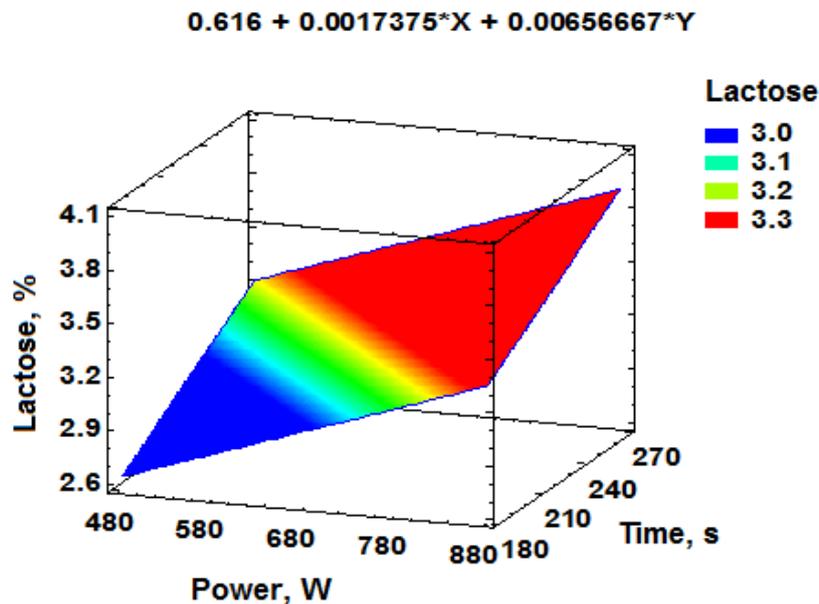


Figure 5. Yogurts lactose values depending on pasteurization regimens

In order to evaluate how the fermentation process was affected by the pasteurization regimens, the variation of lactose and fat content between the raw materials and the obtained yogurts was calculated. So, lactose content suffered the following fluctuations: for yogurt A lactose content decreased with 29.49 % considering the M 100 % value (from 4.51 % to 3.18 %), for yogurt B the reduction value was of 30.81 % (from 4.77 to 3.30 %) and for yogurt C the variation was of 30.60 % (from 4.64 to 3.22 %). The fat content reported to dry substance content undergone the variations: for yogurt A it suffered a breakage of 10.88 % considering the M 100 % value (from 29.68 % to 26.45 %, values obtained by reporting to the dry substance content), for yogurt B it decreased with 9.77 % (from 29.86 % to 26.94 %) and for yogurt C it dropped with 19.37 % (from 29.63 % to 23.89 %).

Taking into consideration the variation of fat and lactose content and the acidity values of the obtained yogurts the following conclusions derived:

- Yogurt A has a medium value for acidity, of 87°T, which can be explained by the fact that the fat content reported to dry substance decreased in a medium rate of 10.88 % compared to the other yogurts, so the lipolysis phenomenon was less intense, lipases being more affected by this regime than by the others. However, lactose suffered the lowest variation, decreasing with 29.49 %, not much different to the other two regimes.
- Yogurt B has the lowest value for acidity, 85°T which can be justified by the fact that the fat content decreased least of all, of only 9.77 % maybe because of a reduced lipolysis (phenomenon which can explain the smallest average grade obtained for the smell), lipases being most affected by this regime of pasteurization, phenomenon that can be supported by the highest variation suffered by lactose during this type of treatment, which decreased with 30.8 % generating the highest quantity of lactic acid during thermostatisation process.
- Yogurt C has the highest acidity value of 93°T which can be explicated by the fact that fat value suffered the highest diminution, of 19.37 %, during this process being generated the highest quantity of free fat acids due to a higher fat hydrolysis engendered by lipases which were not affected very much by this type of pasteurization. Also, lactose had a medium

variation considering the other regimes, of 30.60 %, being transformed by the lactic bacteria in lactic acid during the fermentation process.

4. Conclusion

The present study examined the effects of the variation on the electrical power of a microwave oven during high pasteurization on the obtaining of probiotic yogurt. After several investigations, considering mostly the organoleptic and the physical-chemical characteristics of the yogurts obtained, the authors conclude that the most appreciated yogurt was yogurt B, obtained by heating of raw milk in the microwave oven set on the 80 % (640 W) power, for 240 s (4 minutes). This yogurt received the highest overall average of the organoleptic assessment, of **4.768** and also had the lowest acidity value, of 85°T.

As a recommendation considering yogurt production, an appreciable yogurt can be obtained by pasteurization of raw milk in the microwave oven set on the 80 % (640 W) power, for 240 s (4 minutes) until the temperature of 90°C, due to its organoleptic characteristics and also to a reduced lipolysis and an adequate fermentation process.

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