RESEARCH ON THE PROCESS OF OBTAINING BUTTER IN LABORATORY CONDITIONS
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CERCETĂRI PRIVIND PROCESUL DE OBȚINERE A UNTULUI ÎN CONDIȚII DE LABORATOR

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ABSTRACT
Optimizing the process of obtaining butter requires experiments in laboratory conditions, where some parameters need to be adjusted and monitored. For a low-capacity churn with a horizontal semi-helical paddle, the beating time was determined depending on the speed of the beater and the fat content of the cream. At a fat content of 30% in the cream, the butter percentage obtained at low speeds was 27.7%, while for a speed of 3000 rpm a butter percentage of only 21.3% was obtained. The paper also presents other results necessary for establishing the functional parameters of small churns.

REZUMAT
Optimizarea procesului de obținere a untului necesită experimente în condiții de laborator, în care unii parametri este necesar a fi reglați și monitorizați. Pentru un putinei de capacitate mică, cu o paletă orizontală semielicoidală, s-a determinat timpul de batere în funcție de turația bătătorului și conținutul de grăsime al smântânii. La un conținut de grăsime de 30% în smântână, procentul de unt obținut la trepte joase de turație a fost de 27,7%, în timp ce pentru o turație de 3000 rpm s-a obținut un procent de unt de numai 21,3%. Lucrarea prezintă și alte rezultatele necesare stabilirii parametrilor funcționali ai putineielor de capacități mici.

INTRODUCTION
Butter is a dairy product, composed of fat, water and non-fat dry matter, which is obtained through thermal and mechanical treatments of the cream. According to the Regulation 1308/2013, as well as the Romanian Order 524/2002, butter is defined as the product with a milk-fat content of not less than 80% but less than 90%, a maximum water content of 16% and a maximum dry non-fat milk-material content of 2%. In addition, according to the national legal regulations (Romanian Law 307/2022), butter is the product obtained exclusively from milk components, being a water-in-fat emulsion, with a fat content of at least 80%. It is obtained by processing the pasteurized cream, derived from milk, manufactured in compliance with technical quality conditions.

Cream, as raw material for butter, is the layer of fat that forms naturally on the surface of milk, through the slow agglomeration of fat globules that emulsify. It is removed from the surface of the milk by creaming or extracted from the milk by centrifugation in a cream separator and is characterized by a high fat content. Usually, for the cream used in the butter production, has at least 30% fat in weight percentage. From a physico-chemical point of view, cream is an oil-in-water emulsion, with the sizes of milk fat globules in the range of 0.1-15 µm (*Romanian Law 307/2022; Panchal et al., 2021*).

The methods used to make butter (the Fritz process and batch-wise churning) basically turns the cream into butter grains and buttermilk by agitation and by beating air into the cream. The microstructure of the butter grains as well as of the finished butter is characterized by a dispersion of water, air, fat crystals and fat globules in oil. The consistency of butter can be influenced to a large extent by temperature treatment of the cream (physical cream ripening) (*Amare, 2020*; *Frede and Buchheim, 2007*).

From technological perspective, butter is obtained through the churning of the cream, followed by the removing of the excess liquid phase (buttermilk).

It is a specific food matrix with a specific texture and flavour in particular defined mainly by the lipids, which have a significant impact on the texture (hardness, plasticity, adhesiveness and viscosity, as well as cuttability and spreadability) and rheology, as well as on the sensory properties such as the mouth-fullness and colour (*Wright et al., 2001; Matuszek, 2010; Pădureț, 2021; Chudy et al., 2022; Pavlova et al., 2022*).

From the point of view of colloidal physics, butter is a water/oil emulsion, compared to cream which is an oil/water emulsion (*Serdaroglu et al., 2015; Romanian Order 524/2002*). Its classification is done according to:

- the origin of raw material (milk cream, whey cream, buttermilk cream, frozen cream);
- the acidity of the cream (sweet or fermented);
- the added ingredients (salt, sugar, honey, vegetable fat);
- thermal and mechanical processing procedures (pasteurized or sterilized, melted, powdered, remixed, anhydrous fat from butter).

An important factor that determines the correct evolution of the churning process is the temperature of the cream which varies depending on the season (in the case of production facilities not having a strictly controlled environmental temperature) and the type of butter manufactured. The ripened and chilled cream is brought to the churn. The degree of filling of the churn is 40-50% in its total volume, if the fat content of the cream varies between 25% and 37%. During the first 3-5 minutes of churning, the churn stops 1-2 times and, through a special valve, gases which create an overpressure in the beater and can increase butter losses are evacuated from it (*Celik and Bakirci, 2000; Funahashi and Horiuchi, 2008; Fred and Buchheim, 2007; Lee and Martini, 2018; Kalla et al., 2016; Sun et al., 2008*).

The churning process takes 45-60 minutes and is influenced by several factors. The cream is churned until grains of butter with a diameter of 3-5 mm are obtained, then the churn stops and the buttermilk is removed - through a sieve or cheesecloth – draining it into the buttermilk collecting vessel. The moment when the butter grain achieves the desired size should be carefully observed. If the churning is stopped too early, the butter grain will be smaller and the buttermilk will be more difficult to separate, making also the washing process of the grain more difficult. If the churning is stopped too late, the butter grain will have a larger diameter, more buttermilk will be retained in the grain, the water content will be higher and the preservation of the butter will be reduced (*Frede and Buchheim, 2007; Vithanage et al., 2009*).

The fat content of the buttermilk must be 0.2-0.3% and the temperature must be 2-3°C higher than the temperature of the cream at the beginning of the churning. The butter grain is then washed to completely remove the buttermilk. The temperature of the washing water is determined according to the consistency of the butter. If the consistency of the butter grain is normal, the temperature of the washing water should be equal to the temperature of the buttermilk. If the consistency of the butter grain is soft, then the washing water with a temperature 1-2°C lower will be used and in the case of butter grain with a hard consistency the washing water with a temperature 1-2°C higher than that of buttermilk must be used.

The working parameters of the churn are set according to the consistency and temperature of the butter. The rotation speed of the churn is set at 7-10 rpm. The kneading temperature is set according to the strength of the butter and varies between 7-11°C in summer and 9-13°C in winter. It is regulated by sprinkling the churn with washing water. After 3-5 minutes from the start of the kneading process, the churn is stopped and the excess of water or buttermilk is removed, and the kneading is continuing afterwards.

The characteristics of the butter churning process are affected by the fat content of the cream, the flow rate of the cream and especially by the feeding temperature of the cream, which influences the water content of the butter (*Funahashi and Horiuchi, 2008*). An analysis of the churning process indicated that the water content of butter decreases with increasing the beater shear speed and, after reaching a minimum level, increases linearly. In addition, the way of feeding and the feed administered to dairy animals influences the physical properties of butter and affects its processing properties (*Avramis et al., 2003*).

At low speeds of the whipping arm (approx. 60 rpm), it is considered that the optimal parameters of the process of transforming cream into butter are obtained by stirring it at a temperature of 10°C (*Kalla et al., 2016*). The same authors specify that the stirring temperature, the stirring speed and their interaction have a significant effect on the stirring time and the quality of the butter, if the other parameters, such as acidity, fat percentage, temperature and ripening time, were kept constant (*Sinha et al., 2015*).

Previous experiments show that mixing camel milk with goat milk improves mixing efficiency and microbial quality of butter obtained at different mixing levels. Although butter can be made from pure camel milk, the stirring and fermentation time is longer (Asresie *et al., 2013*).

Also, organoleptic properties such as colour, aspect, taste and texture were optimized when butter samples were prepared from 35% fat cream at a stirring temperature of 10-12°C, compared to cream having 30% and 40% fat content (*Siddique et al., 2011*). Thus, the fat content of the cream and the mixing temperature affect the yield and quality of the butter, influencing the quality parameters.

A longer cream ripening time results in larger butter grains, higher viscosity and a higher solid fat content. Both ripening time and stirring time have an effect on the thermal behaviour of the cream. The stirring time decreases significantly with increasing ripening time, and the crystallization state that promotes partial coalescence (i.e., the aggregation of butter grains) is obtained in the first hour of cream ripening at 10°C (*Buldo et al., 2013*). Heat transfer is influenced by the size of the ripening vessel (a larger vessel results in slower latent heat transfer). Furthermore, the flow of fat globules during agitation is affected by the speed and type of impeller. Therefore, the crystallization time and thus the rate of partial coalescence of milk fat globules is different for different types of churn.

Cream ripening is an important process that influences the production time and the production of butter with a constant quality. The hardest butter was obtained from cream matured at 5°C with stirring at 240 rpm, respectively at 10°C with stirring at 40 rpm. A softer butter was obtained from cream matured at 10°C with stirring at 240 rpm, which also had the highest water content. Other researches (*Lee and Martini, 2018*) show that the hardness of the butter can be adapted by changing the ripening conditions of the cream, which can be ripened at higher temperature with low agitation without changing the hardness of the butter.

Therefore, the working conditions, the stirring time, the type of batter, the physico-chemical characteristics of the raw material such as temperature, are just a few elements to consider when making butter, regardless of the origin of the milk (*Lapcikova et al., 2022* ; *Mtibaa et al., 2021; Panchal et al., 2021; Tsedey et al., 2018; Pavlova et al, 2022*). For example, since the butter’s functional properties are directly influenced by the crystallization of milk fat globules during maturation of cream, the type of cooling (e.g. rapid versus slow cooling) can contribute to a significant difference in butter firmness (*Panchal et al., 2021; Lapcikova et al., 2022*). By applying different procedures for obtaining butter, using manual or electric churns, it is possible to highlight the influence of various process parameters (such as speed of the paddle, temperature and fat content of the cream as raw material in the churning process) on the technological parameters such as the yield in butter (*Rønholt et al., 2012; Rønholt et al., 2014; Lapcikova et al., 2022*).

The objective of this work was to identify the influence of speed and stirring time on the butter yield and its physico-chemical characteristics when processing cow's milk cream with a fat content of approximatively 30%, 35%, and 40%.

MATERIALS AND METHODS

In the experiments performed, an electric churn was used, designed and made from a vessel of approx. 4 litres, to which a Fasco 50747-D500 7021-1641 motor was added, with nominal speed 3000 rpm, three-speed adjustable, 1/100 hp, 52 Amps, 115 Volts 60/50 Hz, with thermal protection.

The motor shaft is ϕ8 mm, and a rectangular, helically inclined beater paddle was attached to its end so that the cream has an up-down movement. The cream moves to the edge, up, out, and back to the centre in a small swirl. The engine was attached directly to the lid of the vessel. In order to have stability during the beating process, and the vessel was placed on a solid support.

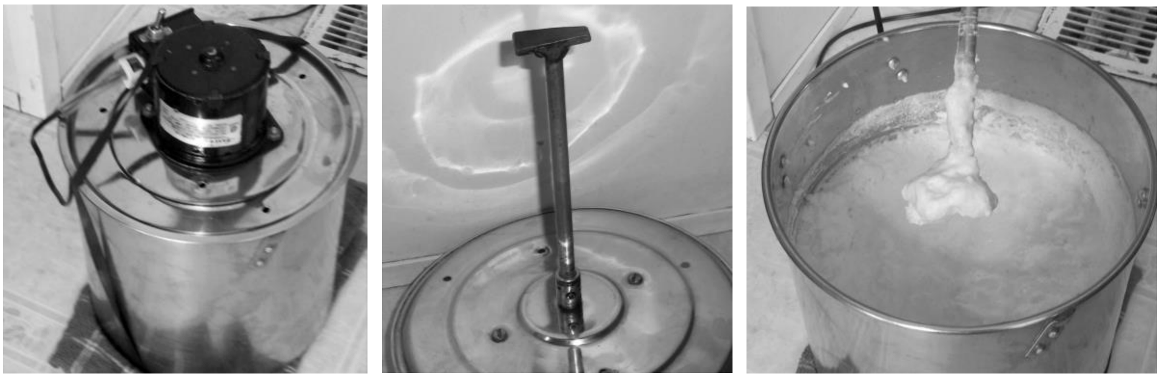

Fig. 1 - Electric churn used in the experiments: general appearance and the stirrer shaft with the stirring paddle

The determination of the dry matter content in cream was performed by the method ISO 6731:2010.

The determination of fat content in the samples of cream was performed by the acido-butyrometric method (*Gerber method*), using a Super Vario N centrifuge for butyrometers and specific butyrometers (*Funke-Gerber, Berlin, Germany*).

The determination of the acidity was performed by the titrimetric method (titration with a 0.1N sodium hydroxide solution in presence of phenolphthalein 1% solution in ethyl alcohol 96% vol.).

The determination of pH was performed using the potentiometric method.

The determination of the moisture content and the non-fat solids content in butter was performed by the method ISO 3727-1 and ISO 3727-2 respectively, and the fat content was calculated based on the method ISO 3727-3.

In each experiment, a quantity of 1.5 kg of cow's milk cream was used, from each category (mentioned in Table 1). The cream was procured from the local market, coming from the store of Pantelimon Dairy Farm.

The determinations were made in the laboratory of ICA Research & Development, both for the raw material and for the finished product.

To determine the physico-chemical characteristics of the raw material used in the experiments and presented in table 1, the following pieces of equipment were used: Mettler Toledo laboratory pH-meter, measurement range 0–14 pH units, 1% resolution; Kern 770 analytical balance, used for masic analysis in acidity, fat and dry matter determination, precision 0.0001 g, operating temperature 10-30°C; Super Vario N centrifuge, used to determine the fat content of cream and butter, 600-1130 rpm; Sanyo Owen OMT oven for the determination of dry matter, with a capacity of 60 litres and an adjustable temperature of 5–300 °C.

After pouring the cream into the laboratory designed churn, the electric motor was started (the speed setting being previously adjusted). At first the noise produced by the paddle was more intense, and as the butter grains began to form, the noise faded. The end of the churning process was visually assessed at the time of separating the butter beans from the buttermilk.

The formed butter was collected and washed three times using tap water, with the last wash adding ice to improve the consistency of the product. The remaining water was drained through a cheesecloth, and the butter was placed in the refrigerator (4-6°C), to be kept for laboratory testing.

The purpose of the experiments was to identify the influence of paddle speed and beating time on butter yield (finished product) at different fat content of cream, respectively determining the characteristics of the finished product (dry matter and fat content), taking into account the characteristics of the raw material.

RESULTS AND DISCUSSION

The determined values of the physico-chemical parameters of the raw material are presented in Table 1.

Table 1

Physico-chemical parameters of the cream used to obtain butter

Physico-chemical parameter	Cream, approx. 30% fat	Cream, approx. 35% fat	Cream, approx. 40% fat
pH	4.95	4.58	4.87
Acidity, (º Thorner)	57.90	50.94	58.47
Fat, (g / 100 g)	31.55	36.12	45.42
Total dry matter, (%)	35.53	40.92	49.87

The literature provides for the calculation of the probable amount of butter, the following calculation formula (1):

$$C_u = \frac{C_s + (G_s - G_m)}{G_u - G_m}\left(1 - \frac{P_u}{100}\right) \tag{1}$$

where: C_u – amount of butter obtained (kg); C_s – amount of cream used (kg); G_s – fat content of the cream (%); G_m – fat content of the skimmed milk (%); G_u - fat content in butter (%); P_u - fat loss during manufacturing (%).

In general, the density of the cream after normalization fell within the limits prescribed by specialized literature, respectively: for cream with 8-10% fat – 1,024 g/cm^3, for cream with 20% fat – 1,018 s/cm^3, for cream with 35% fat - approx. 0.998 g/cm^3.

From the experimental determinations carried out in the laboratory, the following results for the yield in butter were obtained for different types of cream and different blade spades (Table 2).

Table 2

Data obtained from experimental determinations

The type of cream	**30% fat**		**35% fat**		**40% fat**	
Blade speed, (rpm)	Time (min)	Resulting finished product (g)	Time (min)	Resulting finished product (g)	Time (min)	Resulting finished product (g)
1 – 1000 rpm (T1)	55	415	51	495	45	527
Step 2 – 2000 rpm (T2)	44	362	42	434	31	461
Step 3 – 3000 rpm min (T3)	30	320	28	396	17	423

Based on the results obtained, it can be underlined that the fat content of the cream used influences the beating time. This can be explained by the fact that closer fat globules join together faster and cause coalescence in a shorter time.

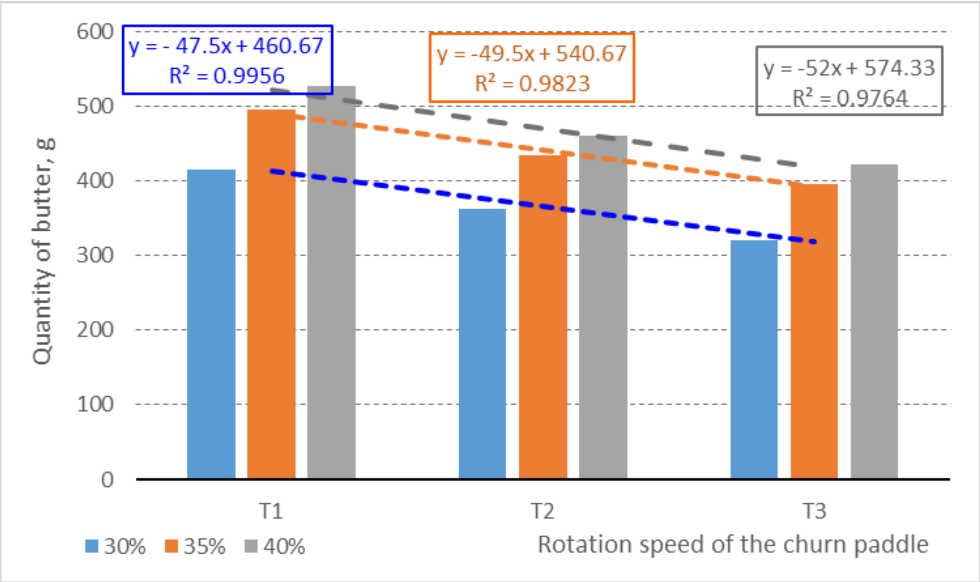

Fig. 2 - The variation of the amount of butter obtained, depending on the speed of the agitator

Figure 2 shows the variation of the amount of butter obtained during churning, depending on the speed of the agitator, for the three fat contents of the initial cream.

For the batch with a higher fat content, the churning time was shorter, comparing to the batch with a lower fat content (30%) for which a longer churning time was required to separate the butter from the buttermilk. However, it was demonstrated that when reducing the churning time, through the increase of the speed of the shaft with the agitator paddle, the amount of separated butter decreases, for the same fat concentration of the cream, and a large part of the fat remains in the buttermilk (and is considered as “lost”).

For the samples where a higher speed was used, there were higher losses of fat in the buttermilk, which caused a low butter yield of the process.

Figure 2 reveals that for different speed steps, increasing from 1000 to 3000 rpm, the amount of butter decreases linearly with the speed, presenting a correlation coefficient R^2 of 0.976, for a fat concentration of the cream of approx. 40% and 0.996, for an initial fat concentration of approx. 30%.

Making a different analysis of the data in table, a linear variation of the values of the butter quantity obtained through churning, for each speed of the mixer, is also found, depending on the fat content of the cream used as raw material.

The correlation with the experimental data shows a correlation coefficient R^2 with decreasing values from low speed to high speed, with values between 0.942, for speed step T1 and 0.929 for speed step T3. This phenomenon is shown in Figure 3, (a,b,c).

It should be noted that *Lee and Martini* (*2018*) obtained the hardest butter when the cream was ripened at 5°C at a beater speed of 240 rpm, respectively at 10°C and a speed of 40 rpm, i.e. for cold cream and higher speed or for cream at a higher temperature and lower speed.

If the cream has higher temperature, and the churning speed is also higher, then a softer butter with a higher water content is obtained. The work of these authors shows that the hardness of the butter can be adapted by changing the ripening conditions of the cream, respectively by correlating it with the speed of the stirring paddle(s).

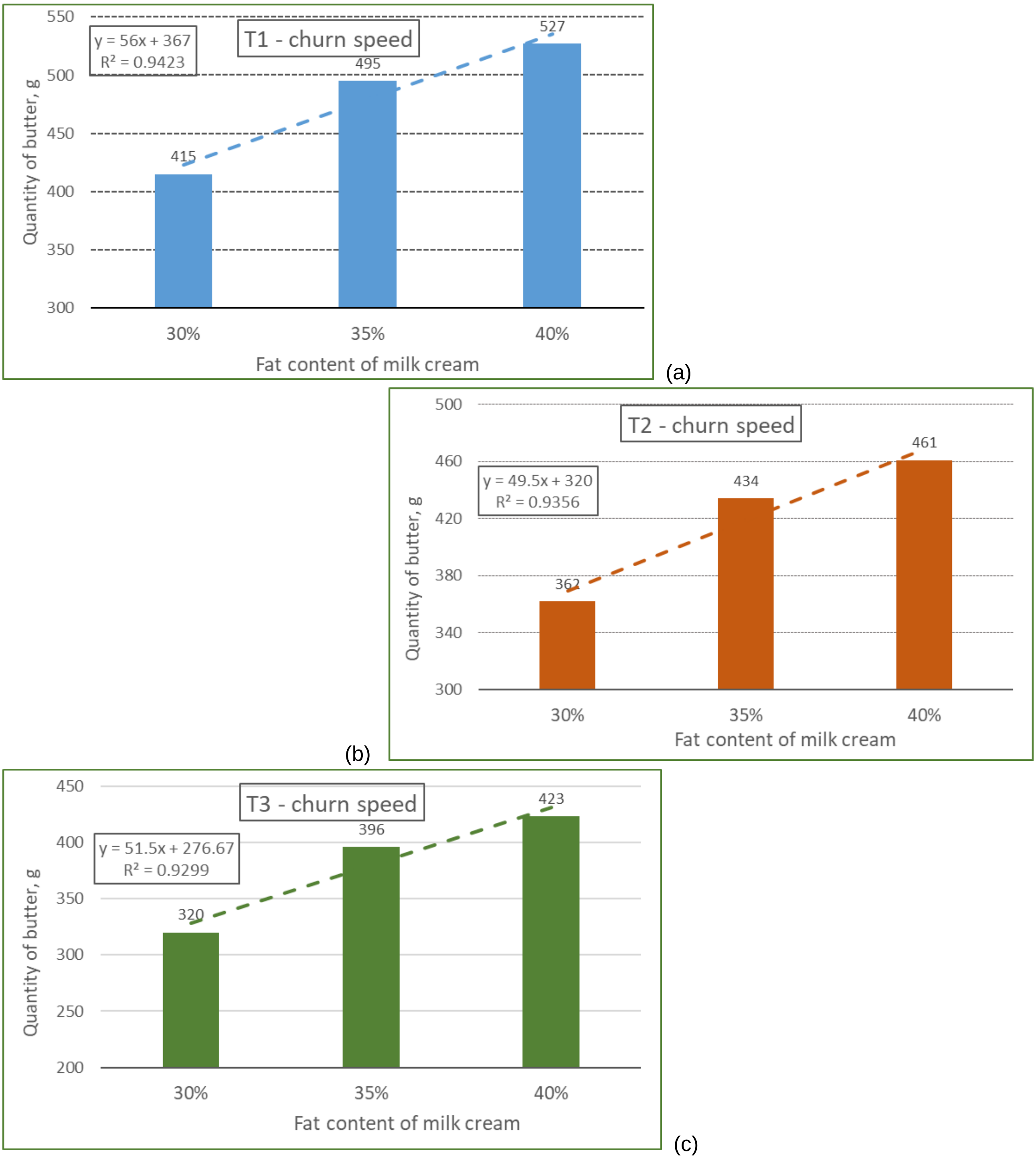

Fig. 3 - The variation of the amount of butter obtained during beating, depending on the fat content of the cream, for the three speeds of the mixer (a,b,c)

Therefore, the aging temperature of the cream and the convenient choice of the functional parameters of the cream are very important.

The cream ripening temperature and stirring speed have an effect on lipid crystallization and processing behaviour, respectively on butter hardness.

Figure 4 shows the variation of the beating time, in order to separate the butter, for the three speed steps of the agitator, from 1000 rpm to 3000 rpm , at the three fat contents of the cream.

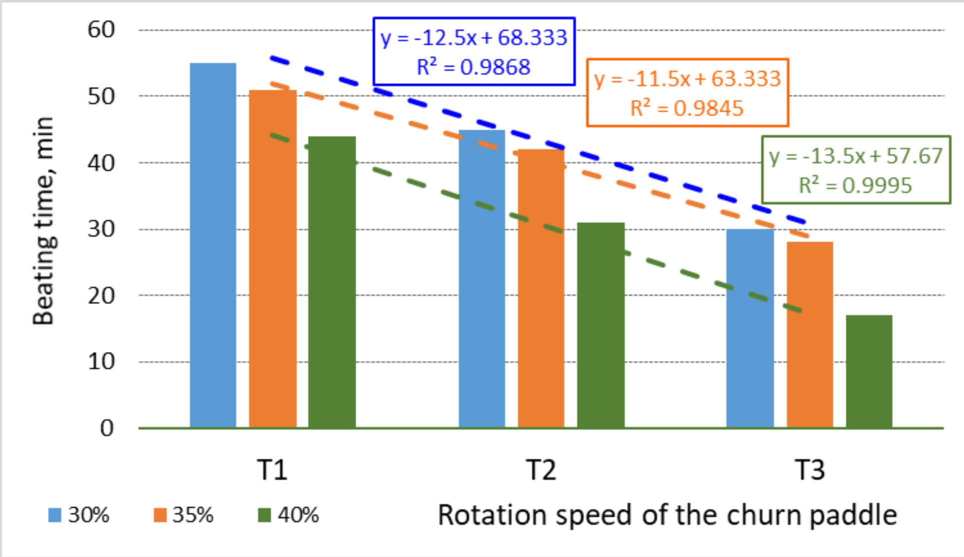

Fig. 4 - The variation of the churning time, depending on the fat content of the cream, for the three speeds of the mixer

As stated before, the churning time decreases with both the speed of the agitator and the increase of the fat concentration, showing a decreasing linear variation. For the three speed steps, increasing the correlation coefficient R^2 of the beating time with the speed of the agitator, also shows decreasing values from 0.987 for cream with a fat content of approx. 30% to 0.999 for cream with a fat content of approx. 40 % (Fig. 4).

It should be mentioned that all the cream used in the experiments was kept in the refrigerator overnight, and batches of 1.5 kg were taken from the total quantity of cream to perform each experiment, so that the cream subjected to the tests had a starting temperature of experiment of about 10 °C. This value supports the statement from the work of the authors *Kalla et al. (2016)*, who mention that the optimum parameters of stirring time and moisture content were obtained when the cream was stirred at a churning temperature of 10 °C. Using suitable conditions of temperature and speed, high quality butter can be produced also in domestic or laboratory conditions.

Table 3

Experimental parameters of electric potential

	Product 1		**Product 2**		**Product 3**	
The speed of the stirring paddle	Dry matter (%)	Fat (%)	Dry matter (%)	Fat (%)	Dry matter (%)	Fat (%)
Step 1	66.53	65.3	70.43	69.09	81.43	80.3
Step 2	66.84	64.44	69.84	68.54	80.84	79.31
Step 3 (3000 rpm)	67.02	63.19	69.02	67.81	80.52	78.81

From the works studied and from our observations, it was found that it is necessary to wash the butter with cold water, several times, after draining the buttermilk. The cleaner the butter is, the more resistant it becomes to usual storage conditions, not going rancid for a longer time, especially if it is well pressed. After that, the butter must be cooled and removed from the mold. Normally, from 100 litres of milk, 8 to 12 litres of cream can be obtained, respectively about 4 kg of butter and 5-6 litres of buttermilk, which can be bottled or further processed.

When analysing the dry matter and the fat of the resulting finished product, the following values were obtained.

The results obtained do not show significant differences, and the fat content of the finished product is different in the three samples because cream with different fat content was used, under different processing conditions.

For raw material with high fat content the water content of the butter decreases, and this aspect is important because the legislation takes into account only the non-fat dry substance for butter.

In this situation, it can be argued that the speed does not have a major impact on the physico-chemical parameters, but as can be observed, at higher speeds the losses are significant.

The determined values classify the obtained butter, according to the product standard, either as type A table butter, the first 2 products, or superior butter for the third one.

From the obtained result, at a fat content approx. 30% of the cream, the yield in butter obtained at low speeds of rotation was 27.7%, while for a rotation of 3000 rpm a yield in butter obtained was only 21.3 %. If the fat content of the cream is approx. 40%, then the yield in butter obtained also increases, so that its values become 35.1% for low speed and 28.2% for high churning speed.

CONCLUSIONS

In correlation with the research of other specialists in the field, the initial characteristics of the cream influence the physico-chemical characteristics of the butter. For the experimental tests presented in this paper, a manufactured electric churn with a single semi-helical stirring paddle, arranged horizontally at the end of a vertical shaft, was used. The speed of the agitator was adjustable in three steps, and the maximum speed specified on the electric motor was 3000 rpm.

The research carried out showed that the higher the speed of the stirring paddle is, the smaller the churning yield obtained, regardless of the initial fat content of the cream.

In addition, the functional parameters of the butter churn are very important for the final characteristics of the butter. Thus, the churning time decreases linearly with the increase of the speed of the mixer and with the increase of the fat content of the cream, until phase separation (butter grains from buttermilk).

For the samples where a higher speed was used, there were higher losses of fat in the buttermilk, which causes a low butter yield of the process.

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