AUTHORS: Dragana Šoronja-Simović, Zita Šereš, Ivana Nikolić, Olivera Šimurina, Marijana Đorđević, Nikola Maravić

Challenges related to the application of high and low *trans* margarine in puff pastry production

Dragana Šoronja-Simović[1], Zita Šereš[1], Ivana Nikolić[1], Olivera Šimurina[2], Marijana Djordjević[1*], Nikola Maravić[1]

[1]University of Novi Sad, Faculty of Technology, Department of Carbohydrate Food Engineering, Bul. cara Lazara 1, 21000 Novi Sad, Serbia
[2]University of Novi Sad, Institute of Food Technology, Bul. cara Lazara 1, 21000 Novi Sad, Serbia

ABSTRACT

Characterization of physicochemical properties of puff pastry margarine and their relationship with final product quality was investigated. The experiment involved the addition of two margarine samples (MLT and MHT), with different *trans* and saturated fatty acids content, in different quantities (35, 45 and 55% on flour basis) and with different relaxation time allowed between laminating (15, 30 and 45 min).

The results showed that MLT margarine (low *trans*) had statistically significantly lower solid fat content, firmness and approximately 1.5 times lower yield stress compared to MHT margarine. Inadequate physical characteristics of MLT margarine, regardless from the independent variables, lead to bad quality of obtained puff pastry, while MHT margarine, despite the high content of TFA, enable obtaining of pastry with good sensory quality.

The obtained results indicate that the quantity of puff pastry margarine and the relaxation time need to be adjusted to the physicochemical characteristics of the margarine.

PRACTICAL APPLICATIONS

Bakery products such as puff pastry are products with high energy value as a consequence of high fat content that has a crucial role in formation of product flaky texture. The puff pastry margarines are commonly obtained by partial hydrogenation and thus, these fats contain significant amounts of *trans* and saturated fatty acids that are harmful for health. Considering previously stated facts incorporation of low *trans* margarine in puff pastry it's a new challenge in developing of novel healthier product. This study explores the application of low and high *trans* margarine, at different substitution levels and different relaxation time

[*]Corresponding author at: Bul. cara Lazara 1, 21000 Novi Sad, Serbia. Tel: +381 69 0203455;
E-mail address: maridjo@tf.uns.ac.rs (M. Djordjević).

allowed, as well as correlation between margarine physicochemical properties and quality properties of puff pastry.
Keywords: *puff pastry; fat composition; physical properties; sensory evaluation*

INTRODUCTION

Production of puff pastry is different from production of other bakery products because of special way of incorporating fats and applying different methods during the processing of dough. The typical characteristic of puff pastry dough is layered structure that is obtained by repeated folding and sheeting process (Renzetti *et al*. 2016), while the baked product has a special puff and flaky texture and alveolar structure with horizontally distributed irregular bubbles (Deligny and Lucas 2015). According to the requirements set for the quality of flour and fats for laminating, type of ingredients and way of handling the dough, the production of puff pastry is one of the most complex processes in bakery (McGill 1981). In order to obtain an appropriate and uniform quality of pastry, beside the knowledge of the technological process, it is important to provide raw materials of adequate quality (Le Bail *et al.* 2005; Costa and Jongen 2006).

The basic raw material composition of puff pastry consist of flour, water, salt, dough fat, fat dedicated to improve workability of dough and puff pastry fat, which has a roll in forming of typical flaky texture of the final baked product (Doerry and Meloan 1986; Fine *et al*. 2006). Unlike fat dough, which incorporates in dough structure, puff pastry fat has a role in separating the dough layers, prevention of their sticking during laminating and trapping of evaporated water during baking in order to ensure expanded volume of final product (Lefébure *et al*. 2013).

The quality of puff pastry to the greatest extent depends on the quality of flour and puff pastry fats, as quantitatively the most present ingredients in dough (Picard 1997). When choosing a puff pastry fat it is essential to focus on parameters that define their technological and sensory quality. The physical characteristics of puff pastry fat, such as firmness, predetermined plasticity and solid fat content (Lefébure *et al*. 2013) have a significant influence on dough handling and process of forming homogeneous and continuous dough/fat layers, as well as their stability at multiple thinning during laminating and pressure of water vapor during baking. These physical characteristics depend on size, number and crystals form of the solid phase, firmness and strength of the crystal lattice, fatty acid composition, viscosity of the liquid phase and to a great extent from solid to liquid phase ratio of triglycerides at particular temperature i.e. high melting point of saturated fats in the fat blend (McGill 1981; Stauffer 1996; Wickramarachchi *et al*. 2015).

Despite the unique sensory characteristics – layered, soft, airy-flaky structure, good melting and pleasant, discreet aroma (Manley 2000; Cauvain and Young 2008) puff pastries belong to the group of products with high energy value. Unfavourable energy value of puff pastry is a consequence of high share of puff pastry fat (from 30 up to 100% on flour basis). Fats in puff pastry products are commonly produced by partial hydrogenation which results in formation of significant amounts of *trans* fatty acids (TFA). In puff pastry margarines the share of TFA is around 25%, while the share of saturated fatty acids (SAFA) is minimum 30%. The fact that SAFAs like lauric (C12:0), myristic (C14:0) and palmitic acid (C16:0) are highly atherogenic (Clarke *et al*. 1997; Müller *et al*. 2001), and that industrially produced TFAs have ten times more pronounced harmful effect on development of heart and cardiovascular diseases (Stender *et al*. 2006), indicates the need to reduce total content of SAFA+TFA in products from laminated dough.

The content of TFA in pastries from laminated dough is significantly different within individual European countries. Minimal content of TFA have products from Greece (1.7%), products from Ireland and the Netherlands around 5.5%, while Danish pastries and croissants from France and Norway have maximum content of TFA 16.8%. Differences in content of

TFA in puff pastries are consequence of differences in composition of puff pastry fats (Van Erp-baart *et al*. 1998). The representation of puff pastry in modern diet on one side, as well as high content of fats (around 30%), SAFA (around 14.5%) and TFA (around 6.5%) on the other, can considerably influence the increase in share of fats and mentioned fatty acids in total daily energy intake.

In order to reduce the content of atherogenic SAFA and TFA in puff pastry, studies in last decade were focused on the application of margarine with modified composition of the fat phase (low fat and low-*trans*). Modified fat phase content of puff pastry margarines often causes modification of their physical and technological characteristics, compared to conventional margarines obtained by the process of hydrogenation. Possible deviations of relevant quality parameters of margarines from the optimal values impose the need for a detailed analysis of influence of fat phase composition on dough handling and quality of puff pastry (Renzetti *et al*. 2016).

The objective of this study was to investigate influence of puff pastry margarines with different composition of the fat phase and physical properties on the physical and sensory parameters of puff pastry quality. The determination of minimal amount of margarine, as well as optimal dough rest period which enable the formation of layered structure of puff pastry is also performed.

MATERIALS AND METHODS

Materials

The puff pastry margarines used for the investigation were: margarine produced by ‘‘Nizegordski maslo-zǐlni kombinat’’, Rusia (denoted MLT), margarine produced by ‘‘Dijamant’’, Serbia (denoted as MHT). Commercially available wheat flour of 13.7%

moisture, ash content 0.45% on dry basis, protein content (N x 5.7) 11.8% on dry basis, wet gluten 25.4% and 57.5% water absorption in farinograpf, was used for all formulation. The analyses were performed according to standard AACC procedures 44-19, 08-01, 46-12, 38-10 and 54-21 respectively (AACC 1995). Margarine Delta (Puratos, Groot Bijgaarden, Belgium), emulsifier DATEM (Danisco Ingredients, Copenhagen, Denmark) and commercially available salts were included in the basic dough.

Physicochemical characterization of margarines

Fatty acid composition of the puff pastry margarine was determined from their methyl esters by gas liquid chromatography-mass spectrometry GC-MS (Hewlett Packard, Stockport, UK) according to ISO 15304 (ISO 2002), using a Hewlett Packard 5890A GLC and a Hewlett Packard 5971A MS. A detailed description of this equipment and the parameters is reported by Simovic *et al*. (2009) and Pajin *et al*. (2011).

The solid fat content (SFC) of the margarines were estimated by NMR, according to the AOCS method number Cd 16 ⁄ 81 (Firestone 1989), at 10, 20, 25 and 30°C.

The textural properties (firmness) of a margarine sample were analysed using a Texture Analyzer (Model TA.XT*Plus*, Stable Micro Systems, Godalming, UK). The firmness of puff pastry margarines was determined by measuring ‘‘work of penetration’’ and ‘‘adhesiveness’’ (penetration tests) at 10, 20, 25, and 30°C. A 5-mm cylinder probe (P/5) was used to penetrate the samples at 2 mm/s to 75% of their original height.

Rheological properties of the margarines were investigated using rotational viscometer HAAKE RheoStress RS600 (Thermo Electron Corporation, Karlsruhe, Germany) with plate–plate sensor PP60 Ti (60 mm in diameter with a 1 mm gap) at 40°C, temperature close to the melting point of samples. Flow properties of puff pastry margarines were determined by measuring the surface hysterisis loop and observing the shear stress (τ) over shear rate (γ).

The margarine samples were exposed to shear rate ramped up from 0 to 200 s^{-1} for 240 s. In the following 120 s, the shear rate was maintained at 200 s^{-1}, and finally ramped down from 200 s^{-1} to 0 s^{-1} for 240 s. The flow curves were distinguished characterized by yield stress τ (Pa) and thixotropic loop area (Pa/s).

Thermal characteristics of margarine samples were determined by differential scanning calorimetry (DSC) using a Q20 DSC (TA Instruments, New Castle, DE, USA). The measurements of temperature (T_t) and change in melting enthalpy (ΔH_t) were performed in an oxygen atmosphere, in the temperature range from 20 to 60°C, at a heating rate of 5°C/min. Determination of the phase transitions, also carried out in an oxygen atmosphere, is conducted by tracking the dependence of heat flow from temperature. The margarine samples were heated from 25°C to 55°C at a rate of 2°C/min, and then cooled at 25°C.

Puff pastry production

The dough was prepared by fallowing formulation: 400.0 g wheat flour, 8.0 g salt, 4.0 g dough fat (margarine), 1.2 g emulsifier and cold water according to farinograph water absorption. The puff pastry production was performed according to Simovic *et al*. (2009). Mixing of dough was conducted in a standard dough mixer for 5 min. Rest period after mixing was 10 min and dough temperature was about 19 ± 1°C. The dough was then sheeted on a Laminoir Marchand LA4-500 to 8 mm thickness. The margarine samples MLT and MHT (35%, 45% or 55% on flour basis) were sheeted to thickness of 8 mm and placed into the dough by English method. After laminating to a thickness of 8 mm the dough was folded by one three-fold (1x3), re-rolled to 8 mm and then folded into fourths (1x4). Afterwards, the dough was refrigerated at 10 °C for different rest periods between laminating of 15, 30 or 45 min. After repeating these steps twice, the pastry sheet with final thickness of 10 mm was cut by a round cutter, allowed to rest for 20 min and baked for 15 min at 220°C.

Puff pastry quality evaluation

The texture properties of puff pastry with MLT and MHT margarines were analysed using a Texture Analyzer (Model TA.XTPlus, Stable Micro Systems, Godalming, UK) with knife edge (HDP⁄ BS) and load cell of 25 kg. The test was carried out 2 h after baking under following conditions: pre-test speed 1.0 mm s^{-1}, test speed 2.0 mm s^{-1}, post-test speed 10.0 mm s^{-1}, distance 55 mm. Total amount of work required for test performing is measured by the area under the characteristic curve (Simovic *et al*. 2009).

The quality of puff pastry was evaluated by defining the physical properties of pastry. Based on the measured values of dough height (H_0), the maximum (Dmax) and minimum diameter (Dmin) of pastry, and the maximum (Hmax) and minimum height (Hmin) of pastry were determined the mean diameter (Dsr) and the mean height (Hsr) of pastry and calculated the following physical parameters:

$$\text{Lift} = (\text{Hmax} + \text{Hmin}) / 2H_0 \qquad (1)$$

$$\text{Volume} = (\text{Dsr}/2)^2 \, \pi \, \text{Hsr} \qquad (2)$$

A point-based method was used for the assessment of the sensory attributes of puff pastry affected by the quantity of puff pastry margarine and the rest period. A six-member board, two hours after baking, evaluated the sensory characteristics of puff pastry by giving the marks based on the 1.0–5.0 grade scale and multiplying them by the previously defined importance coefficients (IC). The panellists were asked to evaluate fallowing quality parameters: external appearance (the shape, colour, surface and crust properties) IC = 1.0; structure (flakiness, flakiness uniformity, pore size, pores wall thickness, colour uniformity)

IC = 1.2; smell IC = 0.8 and taste IC = 1.0. Based on the total sum of the obtained points puff pastry were classified into the following quality categories: excellent (17.6–20.0); very good (15.2–17.5); good (13.2–15.1); acceptable (11.2–13.1) and unacceptable (<11.2) (Simovic *et al.* 2009).

Statistical evaluation

Statistical analyses were performed with Statsoft version 8.0 (StatSoft (Europe), Hamburg, Germany). All experimental results were expressed as mean ± SD of at least five measurements. One-way Anova followed by Duncan's multiple range test were used for comparison of mean values at the significant level of 0.05.

RESULTS AND DISCUSSION

Fatty acids composition

By analysing fat phase composition of margarines MLT and MHT significant differences in content of SAFA, mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA) were found (Table 1). The content of SAFA in margarine MLT is 51.4%, while margarine MHT has significantly lower content of 32.3%. The dominant SAFA in sample of MLT is palmitic acid (C16:0) with content of 44.1%, while in sample of MHT are present palmitic and stearic acid (C18:0) with content of 14.95% and 15.85%, respectively. Content of TFA in MLT sample is 5.4%, whereas MHT sample has 21.8% which is a high value. Since the certain SAFAs (lauric C12:0, myristic C14:0 and palmitic acid C16:0) have negative effect on cholesterol levels, it is important to point out that in MHT sample is registered the lowest total content of these acids (15.7%). In MLT margarine, considering mentioned high content of palmitic acid, total content of atherogenic SAFAs is even 45.7%.

[Please insert Table 1 here]

Mentioned results are expected since the favourable consistency of margarines provides either TFA or SAFA (Nielsen 2006). The MLT margarine is probably been obtained on the basis of palm oil, so the high content of palmitic acid, despite the low TFA content, provides certain firmness of margarine, whereas TFAs and stearic acid have crucial role in achieving optimal consistency of MHT margarine. Maximal content of MUFA 52.4% and PUFA 15.4%, as well as essential oleic acid (C18:1) around 31% is also observed for MHT margarine (Table 1). Based on the share of palmitic acid and TFA it can be assumed that MHT margarine is obtained by the classical method of hydrogenation, while MLT margarine by interesterification or modified hydrogenation of palm oil (Miljanić *et al*. 2002; Tarrago-Trani *et al*. 2006).

From the nutritive point of view is also important the ratio of *cis* PUFA/SAFA, which is in MLT margarine unfavourable (0.20) because, it is significantly below recommended optimal value of 0.50 (World Health Organization 2003). In MHT margarine mentioned ratio is 0.46 and it is in accordance with recommendation of World Health Organization.

Considering many studies which indicate atherogenic effect of certain TFAs (Keyes *et al*. 1965; Hegsted *et al*. 1993; Yu *et al*. 1995; Clarke *et al*. 1997; Howell *et al*. 1997) influence of margarine fat phase composition on increase of total and low density lipoprotein (LDL) cholesterol levels is analysed. Based on the regression model which Müller *et al*. (2001) used to mathematically define influence of particularly SAFAs (C12:0 C14:0, C16:0), MUFAs (C18:1, C18:2, C18:3) as well as TFAs from partially hydrogenised oils (*TRANS* V from plant oil and *TRANS* F from fish oil) on total cholesterol (Equation 3) and LDL cholesterol levels

(Equation 4) it is calculated potential influence of MLT and MHT margarines on risk factors for cardio vascular diseases.

$$\Delta \text{Total cholesterol} = 0{,}01\ \Delta(12{:}0) + 0{,}12\ \Delta(14{:}0) + 0{,}057\ \Delta(16{:}0) + 0{,}039\ \Delta(\textit{TRANS}\ \text{F}) + 0{,}031\ \Delta(\textit{TRANS}\ \text{V}) - 0{,}0044\ \Delta(18{:}1) - 0{,}017\ \Delta(18{:}2{,}18{:}3) \quad (3)$$

$$\Delta \text{LDL cholesterol} = 0{,}01\ \Delta(12{:}0) + 0{,}071\ \Delta(14{:}0) + 0{,}047\ \Delta(16{:}0) + 0{,}043\ \Delta(\textit{TRANS}\ \text{F}) + 0{,}0251\ \Delta(\textit{TRANS}\ \text{V}) - 0{,}0044\ \Delta(18{:}1) - 0{,}017\ \Delta(18{:}2{,}18{:}3) \quad (4)$$

In regression equations 3 and 4 changes in intake of fatty acids are expressed in percentages of energy (%E), while changes of total and LDL cholesterol are expressed in mmol/l.

The obtained results indicate that the composition of margarine fat phase have significant influence on changes in total and LDL cholesterol levels. Changes in total and LDL cholesterol in MLT margarine were 0.93 mmol/l, and 0.73 mmol/l, respectively. Despite the maximum content of TFAs, because of around three times smaller share of highly atherogenic palmitic acid, the influence of MHT margarine on changes in blood cholesterol levels is reduced by as much as 50% compared to MLT margarine. The fact that despite the differences in content of particularly fatty acids sum of SAFA + TFA is relatively equable around 55%, indicates that in the production of special-purpose margarine by decreasing TFA content cannot be avoided increase of SAFA content. Replacement of TFAs with certain SAFAs (lauric, palmitic, stearic) is necessary in order to maintain optimal consistency of margarines (Nielsen 2006). On the basis of previously presented results it can be assumed that the determination of fat phase composition is important in terms of defining its influence on certain physical characteristics of margarine. Potentially enhancement of nutritive value of puff pastry is possible to archive only with determination of minimal amount of margarine for laminating, which will also ensure satisfactory quality of the finished product.

Solid fat content

Plastic properties of margarines are defined by determination of solid fat content (Table 2), and by monitoring the stability of solid to liquid phase ratio in wider temperature interval (from 10 to 30°C). The solid fat content (SFC) of MLT and MHT margarine is equable only at 10°C, whereas at temperatures of 20, 25 and 30°C was statistically significantly lower for MLT margarine ($p < 0.05$). For both margarine samples, the decreasing trend in change of SFC as a function of temperature is pronounced. Similar trend was observed by Lefébure *et al*. (2013). Change in solid triglycerides content is especially noticeable in the temperature interval from 30 to 40°C, as the content of solid triglycerides dicreases from 50 to 60%.

[Please insert Table 2 here]

At temperatures of 10, 20 and 25°C, both margarine samples have a higher content of solid SFC than the values that define plasticity region. Namely, the SFC in the temperature interval from 10 to 30 °C should be from 10 to 25% (Stauffer 1996). The high SFC on lower temperatures can have negative consequence on firmness of margarine and produce certain difficulties in dough handling. At 30°C the SFC for both margarine samples is in plasticity region.

Textural properties of MHT and MLT margarines

The MHT margarine has higher firmness at all tested temperatures, and only at storage temperature (10°C) are not determined statistically significant differences in values of mentioned parameter ($p > 0.05$). Differences in firmness of MLT and MHT margarines at temperatures 20, 25 and 30°C were in interval of 35 up to 50% (Table 2). In the temperature interval from 20 to 25°C were observed the smallest changes in margarine firmness as a function of temperature increase (5 to 15%). The firmness of MLT and MHT margarines at 30°C is considerably reduced with values of 76.2 g and 149.3 g, respectively.

Rheology of MHT and MLT margarines

Flow curves of investigated margarine samples were determined at temperatures which are close to melting points of margarines (40°C). In investigated samples are observed relatively low values of yield stress, 1.5 Pa in MLT and 4.8 Pa in MHT margarine. MHT margarine has three times higher yield stress compared with MLT margarine, which indicates that it is necessary to apply greater force for his destruction. It is assumed that the lower SFC in MLT sample has affected the value of stress shear, which is for approximately 1.5 times lower compared to MHT margarine. According to obtained results, it can be expected that stability of margarine layers between dough layers will be smaller when using margarine with lower stress shear. Based on the analysis of stress shear it can be observed that for MLT sample must be applied two times higher shear rate, which is possibly consequence of high viscosity of continuous phase. The mentioned observations are partially conformed by the results of firmness measurement for MLT margarine. Decrease in firmness by 30 times when temperature increases from 10 to 30 °C, may be result of an increase in liquid phase viscosity and decrease in solid fat phase content (Ghotra *et al*. 2002).

Presence of certain differences in surfaces of thixotropic loops of MLT and MHT margarines (Fig. 1) is probably consequence of differences in structure stability of some margarine samples, regarding to different polymorphic shape that dominates after crystallization (β with strong or β' with wake primary and secondary bonds).

[Please insert Figure 1 here]

FIG. 1. THIXOTROPIC CURVE OF MARGARINE

Based on the surface of thixotropic loop it was observed that MLT margarine is more unstable, because it is necessary to invest minimal energy (0.49 x 10^4 Pa/s) for interrupting of his structure, which partially confirms previous assumptions that the fat phase of MLT margarine crystallize predominantly in β' polymorphic form. Application of MLT margarine in puff pastry, due to low stability, lower and changeable content of solid triglycerides as a function of temperature, will disable the formation of continuous fat film between dough layers and thereby affect the obtention of puff pastry with unsatisfactory quality. The surface of thixotropic loop for MHT sample was three times greater than for MLT (Table 2). Based on literature data (Segura *et al*. 1995) greater surface of thixotropic loop indicates the complexity of rheological system, as well as the possibility for occurrence of significant changes in structure when changing the share rate.

Thermal characteristics

The thermal characteristic of margarines – temperature (T_t) and change in melting enthalpy (ΔH_t) are shown in Table 2. The results indicate that the melting points of MLT and MHT samples have values in the range of majority special purpose margarines (McGill 1981).

The change of melting enthalpy for MHT margarine is 3.5 times higher than for MLT margarine, which according to the literature indicates firmer primary and secondary bonds in three-dimensioned network of solid fat crystals in MHT margarine (de Man *et al*. 1991; Laia *et al*. 2000). Differences in bonds strength are probably a consequence of differences in margarine structure, i.e. polymorphic forms which are dominantly developed during crystallization of margarine fat phase. The crystals of fat in β polymorphic form a large needle agglomerate with strong crystal lattice, while β' crystals are small, fit a large quantity of liquid triglycerides and form lattice with weak primary and secondary bonds (Laia *et al*. 2000;

Ghotra *et al*. 2002). Obtained results confirm the assumption that the MHT margarine obtained by the classical hydrogenation of plant oils crystallize in β polymorphic form. MLT margarine is probably obtained by interesterification of palm oil characterized by β' polymorphic crystal form (Ghotra *et al*. 2002).

Physical and sensory properties of puff pastry

Physical properties of puff pastry with MLT and MHT margarine and results of sensory evaluation of puff pastry quality are presented in Table 3. The obtained results confirmed the majority of assumptions that become apparent after study of chemical and physical characteristics of margarine. Because of unstable content of solid triglycerides as a function of temperature, small firmness at temperatures 20 and 25°C, and low stress shear of MLT margarine it is not possible to obtain puff pastry with desirable physical and sensory properties (Table 3).

[Please insert Table 3 here]

During baking the dough is not lifted enough. In most samples, independently from amount of MLT margarine and dough rest period, the increase in height is even smaller than two times. The addition of 45 and 55% margarine, in samples where dough rest period was 15 and 45 min, improved lifting for 20 to 35% compared to samples with 35% MLT margarine. In samples with dough rest period of 30 min after laminating, increase in amount of margarine causes decrease in lift by 25%. Statistical analyses of results confirmed that the variations in period of dough resting affect the creation of statistically significant differences in lift of puff pastry with 35 and 55% MLT margarine (Table 3).

The values of puff pastry hardness with MLT margarine were in very wide interval from 13.0 to 29.1 kgs. At a constant amount of margarine, the lowest values of hardness were obtained in samples in which dough rest period between laminating was 45 min. The mentioned values of dependent variable are two times lower compared to hardness of samples in which dough rest period was 15 min. Hardness of samples with the shortest rest period does not change significantly with increase in amount of margarine, but changes of tested parameter at the level of 20 to 45% are registered in samples with allowed rest period of 30 and 45 min. The optimal values of independent parameters, which provide minimal firmness of puff pastry, are with 35 or 55% of MLT margarine and allowed rest period of 45 min.

Volume of a large number of samples is lower than 60 cm^3, which is beneath satisfactorily value that will provide optimal quality of puff pastry (Table 3). The largest volume was achieved with addition of 35% MLT margarine and allowed rest period of 15 (75.5 cm^3) and 45 min (70.7 cm^3). By testing the significance in differences of arithmetic means, it is established that increase in margarine content causes statistically significant changes in volume of puff pastry. Increase in dough rest period from 15 to 30 min, in samples with a constant amount of MLT margarine also affects the formation of statistically significant differences in the values of mentioned parameter ($p < 0.05$).

Sensory quality of most samples with MLT margarine was, independently of margarine amount and resting period, bad (unacceptable or acceptable): colour and shape of puff pastry were changed, structure irregular and undeveloped, colour uneven on whole cross section, flavour partially or completely changed, taste was very pasty and unpleasant. In samples with 35% margarine in which dough rest period was 15 and 45 min, taste of puff pastry was partially improved which contributed to an increase in the total number of points, but not in the improvement of entire quality. Addition of 45 and 55% margarine has mostly affected the deterioration of puff pastry structure. Insufficient firmness of margarine and inadequate rheological properties of MLT margarine (Table 2, Fig. 1) did not allowed the formation of continuous fat layers between the dough layers, so the structure of puff pastry with maximal amount of margarine is not appropriate. The best sensory properties and therefore maximal number of points 14.2 were archived by the addition of 45% margarine and allowing the maximal dough rest period. The mentioned sample, despite the deficiencies in structure of puff pastry (less layered), is in category of good sensory quality. Sample has good sensory quality because of high grades for exterior appearance, taste and flavour of puff pastry, shape and colour of puff pastry are slightly modified, crust connected, flavour and taste rounded and distinctive. Based on the analysis of physical and sensory properties of puff pastry it is evident that despite the low content of TFA, MLT margarine is not recommended for production of puff pastry.

Physical and sensory properties of puff pastry with MHT margarine are presented in Table 3. It is assumed that small lift of dough during baking in most samples is consequence of high firmness of MHT margarine at 20 and 25°C, which considerably hamper the laminating and probably leads to tearing and sticking of dough layers. Interrupting of continuous separate and discrete dough and margarine layers did not provide retention of formed water vapour in layers of margarine. Because of that the significant increase in height i.e., lift on baking is excluded. Maximal, but in any case insufficient lift was obtained by addition of 35 or 45% MHT margarine and allowing the rest period of 45 and 15 min, respectively. Statistically significant differences in lift were obtained due to increase in amount of margarine in samples with dough rest period of 15 min ($p < 0.05$). Positive and statistically significant influence of prolonged rest period was confirmed only in pastries with 35% MHT margarine (Table 3). The mentioned results indicate that with variations in technological parameters of production at multiple levels (in this paper was studied the influence of two variables on three levels) is possible to get a more complete picture of the possibilities for increase in dough lift with MHT margarine.

Uneven lift, however, did not have drastic consequences on the values of pastry hardness, which are in the interval from 16.9 to 26.8 kgs. Increase in amount of MHT margarine from 35% to 55% in samples with rest period of 15 min, leads to increase in hardness of pastries up to 100%. The mentioned effect can be a consequence of insufficiently long rest period, because it is assumed that due to high margarine firmness during laminating in dough was developed considerably greater stresses. These results are fully in accordance with the data from the references which confirm that the rest period plays a key role in the relaxation of gluten and in a proper formation of the layered structure of pastry (Cauvain and Young 2001). Similar changes of hardness as a function of margarine quantity, when allowed rest period was 30 min are observed. Previous assumptions are in correspondence with results of hardness measurements as a function of rest period in samples with 55% MHT margarine. However, longer resting period has a negative effect on hardness of puff pastries with 35 and 45% of margarine (Table 3), so for production of puff pastries with addition of relatively small amounts of MHT margarine is not recommended rest period longer than 30 min. Statistical analyses of pastry hardness as a function of margarine quantity and resting period, indicates that the changes in values of one independent variable, at constant value of another, mostly do not affect the creation of statistically significant differences in the values of dependent variable ($p > 0.05$).

The puff pastry volume is in accordance with degree of dough lifting during baking. Extremely low values of volume from 55 to 65 cm^3 were obtained in samples in which accomplished lifting was beneath 3.0. In most samples it is evident the trend of volume increase as a function of increase in margarine content and dough rest period. Addition of 45 and 55% MHT margarine causes increase in volume approximately for 20 to 55%, respectively. Positive effect of a longer dough rest period was noticed in samples with 35 and 45% margarine, while in pastry with 55% MHT margarine decrease in volume for 5 to 20%

was observed. By testing the significance of differences in mean values of volume, it was confirmed that the addition of 55% margarine with dough rest period of 15 and 30 min leads to statistically significant increase in volume of pastry compared to the samples with 35 and 45% margarine (Table 3).

Sensory analyses of quality parameters of puff pastry with MHT margarine (Table 3), indicates that addition of 35% margarine leads to an unsatisfactory sensory quality of puff pastry. Exceptionally compacted and undeveloped structure is formed in sample in which, beside the insufficient amount of margarine, applied dough rest period was 15 min. Longer dough rest period between the laminating procedure enhances the external appearance and structure of puff pastry, which significantly affects the category of quality of puff pastry. The excellent quality of puff pastry was obtained in samples with maximal amount of margarine (Fig. 2).

[Please insert Figure 2 here]

FIG. 2. INFLUENCE OF QUANTITY OF MARGARINE MHT ON PUFF PASTRY QUALITY

Applying of maximal dough rest period has impact on non-flaky structure of pastries with 55% MHT margarine, which reduces the sum of points that define the category of quality for 10%. In samples in which the dough rest period was 30 min, it is notable enhance of taste which manifests with easier bite and better melting of puff pastry. It is assumed that the registered minimal hardness of puff pastry with 45 and 55% margarine (Table 3) has affected the mentioned positive changes in their taste. Optimal physical properties and excellent quality of puff pastry is achieved in sample with 55% MHT margarine and allowed rest period of 15 min - lift 3.8, hardness 19.8 kgs, volume 89.8 cm^3 and total number of points 18.6.

CONCLUSION

Based on the obtained result it can be concluded that low content of TFA cannot be the only and crucial parameter for choosing puff pastry margarine. It is of great importance to define effects of decrease in TFA content on physical properties of margarine. It is also important to adjust the dough rest period between laminating to physicochemical properties of puff pastry margarine. By applying margarine with a higher SFC and strong primary and secondary bonds inside the structure, such as MHT margarine, satisfactory physical and sensory properties of pastry can be achieved and the dough rest period between laminating can be reduced (15 min or max 30 min). On the other side, addition of margarine with lower SFC, smaller firmness and weaker rheological characteristics, such as MLT margarine, lead to unsatisfactory quality of the most pastry samples independently from the amount of margarine and applied rest period. A longer rest period (45 min) is required for obtaining of puff pastry that contains MLT margarine and have acceptable quality.

ACKNOWLEDGMENTS

This study was supported by the Ministry of Education, Science and Technological Development of Serbia.

REFERENCES

AACC. 1995. *Approved Methods 18-01, 38-10, 44-9, 46-12, and 54-21, 9th ed.* American Association of Cereal Chemists, St Paul, MN.

CAUVAIN, S. and YOUNG, L. 2008. *Bakery Food Manufacture and Quality: Water control and effects, 2nd ed*. Wiley-Blackwell Publishing, Oxford, UK.

CLARKE, R., FROST, C., COLLINS, R., APPLEBY, P. and PETO, R. 1997. Dietary lipids and blood cholesterol: quantitative meta-analysis of metabolic ward studies. Brit. Med. J. *314*, 112-117.

COSTA, A.I.A. and JONGEN, W.M.F. 2006. New insights into consumer-led food product development. Trends Food Sci. Tech. *17*, 457-465. http://dx.doi.org/10.1016/j.tifs.2006.02.003

DE MAN, L., DE MAN, J.M. and BLACKMAN, B. 1991. Physical and textural characteristic of some North American shortenings. J Am .Oil Chem. Soc. *68*(2), 63-69. http://dx.doi.org/10.1007/BF02662318

DELIGNY, C. and LUCAS, T. 2015. Effect of the number of fat layers on expansion of Danish pastry during proving and baking. J Food Eng. *158*, 113–120. http://dx.doi.org/10.1016/j.jfoodeng.2014.12.006

DOERRY, W.T. and MELOAN, E. 1986. Croissant technology. AIB Research Department Technical Bulletin. *8*(10), 1-9.

FINE, J.B., PASKA, J.M. and FEENEY, J.F. 2006. *Low trans* puff pastry composition, method of use and puff pastry products. WIPO.WO 2006/133124 A1.

FIRESTONE, D. 1989. *Official Methods and Recommended Practices of the American Oil Chemist´s Society, 5th ed*. Cd 16-81, Champaign, IL.

GHOTRA, B.S., DYAL, S.D. and NARINE, S.S. 2002. Lipid shortenings: a review. Food Res. Int. *35*(10), 1015-1048. http://dx.doi.org/10.1016/S0963-9969(02)00163-1

HEGSTED, M., AUSMAN, L.M., JOHNSON, J.A. and DALLAL, G.E. 1993. Dietary fat and serum lipids: an evaluation of the experimental data. Am. J Clin. Nutr. *57*(6), 875-883.

HOWELL, W.H., McNAMARA, D.J., TOSCA, M.A., SMITH, B.T. and GAINES, J.A. 1997. Plasma lipid and lipoprotein responses to dietary fat and cholesterol: a meta-analysis. Am. J Clin. Nutr. *65*(6), 1747-1764.

ISO. 2002. *ISO method 15304 1st ed*. International Organization for Standardization, Geneva, Switzerland.

KEYES, A., ANDERSON, J.T. and GRANDE, F. 1965. Serum cholesterol response to changes in the diet. 1V. Particular saturated fatty acids in the diet. Metabolism. *14*(7), 776-787.

LAIA, O.M., GHAZALIA, H.M., CHO, F. and CHONG, C.L. 2000. Physical and textural properties of an experimental table margarine prepared from lipase-catalysed transesterified palm stearin: palm kernel olein mixture during storage. Food Chem. *71*(2), 173-179. http://dx.doi.org/10.1016/S0308-8146(00)00084-4

LE BAIL, A., MONTEAU, J.Y., MARGERIE, F., LUCAS, T., CHARGELEGUE, A. and REVEDY, Y. 2005. Impact of selected process parameters on crust flaking of frozen partly baked bread. J Food Eng. *69*, 503-509. http://dx.doi.org/10.1016/j.jfoodeng.2004.09.006

LEFÉBURE, É., RONKART, S., BROSTAUX, Y., BÉRA, F., BLECKER, C. and DANTHINE, S. 2013. Investigation of the influence of processing parameters on physicochemical properties of puff pastry margarines using surface response methodology. LWT - Food Sci. Technol. *51*, 225-232. http://dx.doi.org/10.1016/j.lwt.2012.09.018

MANLEY, D. 2000. *Technology of Biscuits, Crackers, and Cookies, 3rd ed*. Woodhead Publishing Limited, Cambridge, England.

McGILL, E.A. 1981. A closer look at bakery fats. In *Puff Pastry Faults*, (E.A. Mc Gill, ed.) pp. 2-20, Puff Pastry Faults Peerless, Food Products, Liverpool.

MILJANIĆ, S., KARLOVIĆ, Đ., MILOVIĆ, S. and ĐURKOVIĆ, V. 2002. Practical experience in the esterification of edible oils and fats in operational conditions. Journal of edible oil industry. *33*(1-2), 51-55.

MÜLLER, H., KIRKHUS, B. and PEDERSON, J.I. 2001. Serum cholesterol predictive equations with special emphasis on *trans* and saturated fatty acids. An analysis from designed controlled studies. Lipids. *36*(8), 783-791. http://dx.doi.org/10.1007/s11745-001-0785-6

NIELSEN, K. 2006. Is the quality and cost of food affected if industrially produced *trans* fatty acids are removed? Atheroscler. Supp. *7*, 61-62. http://dx.doi.org/10.1016/j.atherosclerosissup.2006.04.014

PAJIN, B., ŠORONJA-SIMOVIĆ, D., ŠEREŠ, Z., GYURA, J., RADUJKO, I. and SAKAČ, M. 2011. Physicochemical and textural properties of puff pastry margarines. Eur. J Lipid Sci. Technol. *113*(2), 262–268. http://dx.doi.org/10.1002/ejlt.201000293

PICARD, N. 1997. Substitution of the animal fat and calorie reduction of an industrial pastry. Master Thesis. Faculty of Agriculture and Food Sciences, Université Laval, Québec (Substitution de la matière grasse animale et réduction des calories d'une pâte feuilletée industrielle. Maître tesos. Faculté des sciences de l'agriculture et de l'alimentation Université Laval, Québec).

RENZETTI, S., DE HARDER, R. and JURGENS, A. 2016. Puff pastry with low saturated fat contents: The role of fat and dough physical interactions in the development of a layered structure. J Food Eng. *170*, 24-32. http://dx.doi.org/10.1016/j.jfoodeng.2015.09.009

SEGURA, J.A., HERRERA, M.L. and AÑÓN, M.C. 1995. Margarines: a rheological study. J Am. Oil Chem. Soc. *72*(3), 375-378. http://dx.doi.org/10.1007/BF02541099

SIMOVIC, D.S., PAJIN, B., SERES, Z. and FILIPOVIC, N. 2009. Effect of low- *trans* margarine on physicochemical and sensory properties of puff pastry. Int. J Food Sci. Tech. *44*, 1235–1244. http://dx.doi.org/10.1111/j.1365-2621.2009.01953.x

STAUFFER, C.E. 1996. *Fats and Oils*. American Association of Cereal Chemists, St. Paul, Minnesota.

STENDER, S., DYERBERG, J., BYSTED, A., LETH, T. and ASTRUP, A. 2006. A *trans* world journey. Atheroscler. Supp. *7*(2), 47-52. http://dx.doi.org/10.1016/j.atherosclerosissup.2006.04.011

TARRAGO-TRANI, M.T., PHILLIPS, K.M., LEMAR, L.E. and HOLDEN, L.M. 2006. New and existing oils and fats used in products with reduced *trans* fatty acid content. J Am Diet Assoc. *106*(6), 867-880. http://dx.doi.org/10.1016/j.jada.2006.03.010

VAN ERP-BAART, M.A., COURT, C., CUADRADO, C., KAFATOS, A., STANLEY, J. and VAN POPPEL, G. 1998. *Trans* fatty acids in bakery products from 14 European countries: the TRANSFAIR study. J. Food Comp. Anal. *11*, 161-169. http://dx.doi.org/10.1006/jfca.1998.0571

WICKRAMARACHCHI, K.S., SISSONS, M.J. and CAUVAIN, S.P. 2015. Puff pastry and trends in fat reduction: an update. Int. J Food Sci. Tech. *50*, 1065–1075. http://dx.doi.org/10.1111/ijfs.12754

WORLD HEALTH ORGANIZATION. 2003. *Diet, nutrition and prevention of chronic diseases, Report of Joint WHO/FAO Expert Consultation*. WHO Technical Report Series, No. 894, Geneva.

YU, S., DERR, J., ETHERTON, T.D. and KRIS-ETHERTON, P.M. 1995. Plasma cholesterol-predictive equations demonstrate that stearic acid is neutral and monosaturated fatty acids are hypocholesterolemic. Am. J Clin. Nutr. *61*(5), 1129-1139.

TABLE 1. FATTY ACIDS COMPOSITION OF PUFF PASTRY MARGARINE

Parameters	**Margarine MLT**	**Margarine MHT**
Fat composition (% of total fatty acids)		
Saturated fatty acids, SAFA	51.36 ± 0.19	32.26 ± 0.26
C8:0	*0.06 ± 0.01*	*0.04 ± 0.02*
C10:0	*0.04 ± 0.01*	*0.03 ± 0.25*
C12:0	*0.37 ± 0.04*	*0.22 ± 0.08*
C14:0	*1.28 ± 0.02*	*0.55 ± 0.14*
C16:0	*44.09 ± 1.13*	*14.95 ± 0.11*
C18:0	*5.02 ± 0.12*	*15.85 ± 0.37*
C20:0	*0.39 ± 0.02*	*0.28 ± 0.02*
C22:0	*0.13 ± 0.01*	*0.34 ± 0.01*
Monounsaturated fatty acids, MUFA	37.03 ± 0.25	52.38 ± 0.96
C16:1c	*0.06 ± 0.07*	*0.04 ± 0.01*
C18:1c	*31.79 ± 0.68*	*31.05 ± 1.95*
C18:1t	*5.19 ± 0.01*	*21.27 ± 0.95*
C20:1c	*0.14 ± 0.16*	*0.02 ± 0.01*
Polyunsaturated fatty acids, PUFA	11.61 ± 0.22	15.36 ± 0.55
C18:2c	*11.48 ± 0.34*	*14.83 ± 0.02*
C18:2t	*0.19 ± 0.07*	*0.33 ± 0.11*
C18:3c	*0.07 ± 0.08*	*0.10 ± 0.02*
C18:3t	*0.07 ± 0.08*	*0.10 ± 0.01*
Trans fatty acids, TFA	5.45	21.80
SAFA + TFA	56.81	54.06
*cis*PUFA/(SAFA + TFA)	0.20	0.28
*cis*MUFA	31.99	31.11
*cis*PUFA/SAFA	0.22	0.46

TABLE 2. PHYSICOCHEMICAL CHARACTERISTICS OF PUFF PASTRY MARGARINE

Parameters	**Margarine MLT**	**Margarine MHT**
Melting point (ºC)	41.2 ± 0.6	40.0 ± 0.4
ΔHt (J/g)	12.3 ± 0.3	45.5 ± 0.7
Solid fat content (%)		
10 ºC	60.7 ± 2.0^{a}	61.4 ± 0.6^{a}
20 ºC	42.3 ± 0.3^{a}	48.2 ± 1.0^{b}
25 ºC	31.3 ± 0.6^{a}	37.9 ± 0.6^{b}
30 ºC	19.8 ± 1.2^{a}	25.3 ± 0.7^{b}
Firmness (g)		
10 ºC	2260.5 ± 274.30^{a}	2449.4 ± 77.1^{a}
20 ºC	322.6 ± 21.0^{a}	499.5 ± 43.7^{b}
25 ºC	281.3 ± 15.2^{a}	429.7 ± 16.3^{b}
30 ºC	76.2 ± 2.8^{a}	149.3 ± 1.9^{b}
Yield stress, τ (Pa)	1,5	4,8
Shear stress (Pa)	171,4	253,7
Critical share rate, γ (s^{-1})	17,0	8,5
Thixotropy loop area x 10^4 (Pa/s)	0,49	1,52

Values followed by different alphabetical letters in the same raw are significantly different ($p < 0.05$)

TABLE .3 EFFECT OF MARGARINE MLT AND MHT ON PUFF PASTRY QUALITY

Independent variable					
x (%)	**y (min)**	**Lift[a]**	**Volume[a] (cm^3)**	**Hardness[a](kgs)**	**Quality category[b]**
			Margine MLT		
35	15	2.58 ± 0.18[a]	75.53 ± 8.04[a]	29.10 ± 5.81[af]	12.7 - acceptable
35	30	1.52 ± 0.16[b]	32.00 ± 2.94[b]	24.67 ± 5.90[acf]	7.6 - unacceptable
35	45	2.69 ± 0.26[a]	70.69 ± 5.39[a]	13.02 ± 0.23[b]	12.7 - acceptable
45	15	1.88 ± 0.26[cde]	43.21 ± 4.74[c]	25.61 ± 3.26[aef]	9.0 - unacceptable
45	30	1.94 ± 0.35[cde]	54.79 ± 8.07[de]	19.44 ± 6.88[abg]	9.0 - unacceptable
45	45	2.12 ± 0.10[c]	52.83 ± 3.08[d]	18.83 ± 5.64[bcde]	14.2 - good
55	15	1.95 ± 0.21[d]	56.45 ± 2.08[d]	28.73 ± 1.79[f]	9.6 - unacceptable
55	30	1.97 ± 0.16[cde]	49.20 ± 2.77[e]	13.45 ± 2.43[bd]	5.6 - unacceptable
55	45	1.73 ± 0.16[be]	53.48 ± 4.67[de]	13.05 ± 5.71[dg]	5.2 - unacceptable
			Margine MHT		
35	15	1.96 ± 0.49[a]	54.79 ± 12.04[a]	17.14 ± 2.76[ad]	8.2 - unacceptable
35	30	2.79 ± 0.44[bd]	60.67 ± 7.92[ab]	22.30 ± 3.19[b]	14.5 - good
35	45	3.52 ± 0.44[ce]	80.54 ± 5.77[ce]	26.77 ± 2.26[c]	14.1 - good
45	15	2.78 ± 0.38[d]	64.28 ± 7.06[ad]	20.48 ± 3.03[ab]	15.7 - very good
45	30	3.16 ± 0.56[bcd]	73.43 ± 9.72[bcd]	20.11 ± 1.33[ab]	14.6 - good
45	45	3.33 ± 0.36[bc]	76.98 ± 6.99[ce]	24.72 ± 9.31[abcd]	16.5 - very good
55	15	3.75 ± 0.64[ce]	93.77 ± 10.24[f]	24.23 ± 6.46[abc]	18.5 - exellent
55	30	3.77 ± 0.13[e]	89.84 ± 11.07[ef]	19.78 ± 6.87[abcd]	18.6 - exellent
55	45	3.14 ± 0.32[bcd]	73.02 ± 9.37[bcd]	16.87 ± 2.03[d]	16.9 - very good

x, quantity of puff pastry margarine, on flour weight basis; y, rest period.

[a] Values followed by different alphabetical letters in the same column are significantly different ($p < 0.05$).

[b] According to the point-based method (max. 20.0).

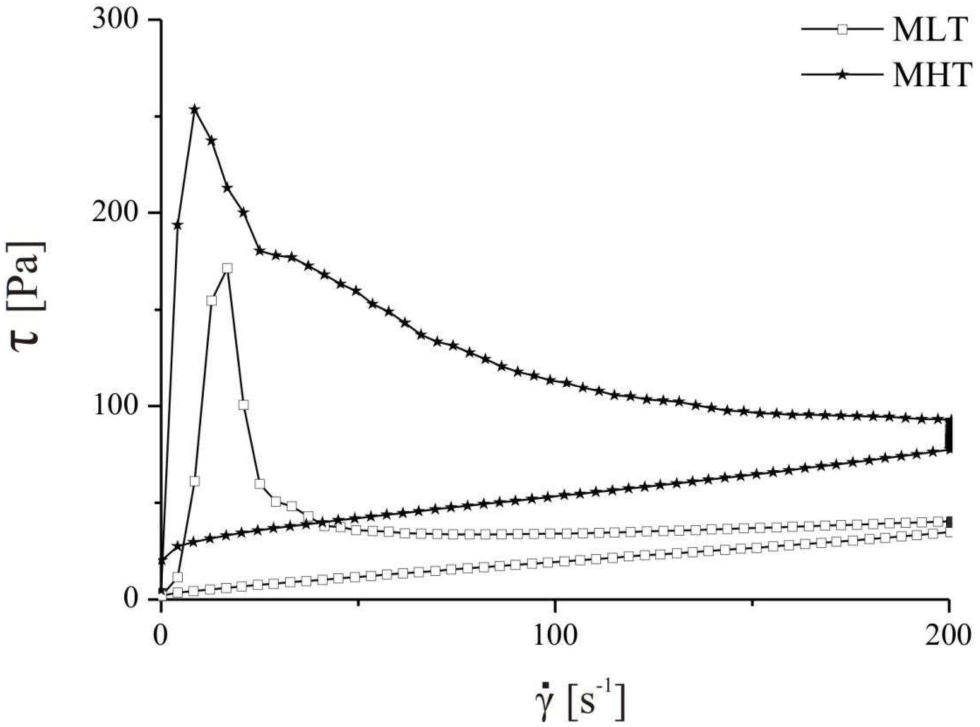

FIG. 1. SHEAR STRESS (τ) AS FUNCTION OF SHEAR RATE ( ): THIXOTROPIC CURVES OF LOW *TRANS* (MLT) AND HIGH *TRANS* (MHT) MARGARINE

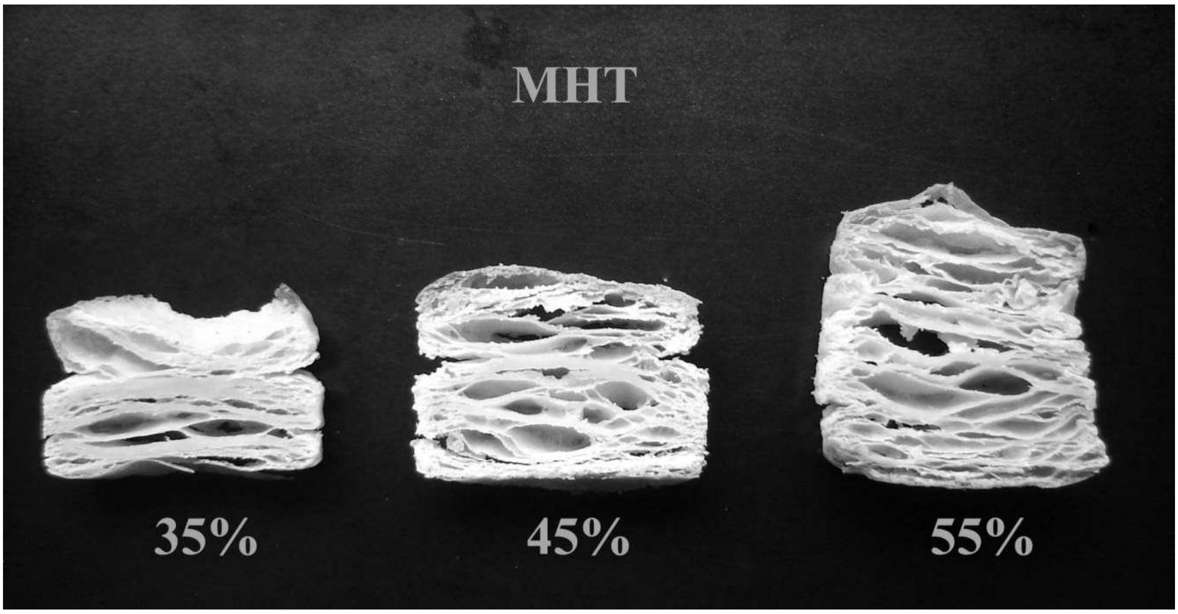

FIG. 2. INFLUENCE OF HIGH *TRANS* MARGARINE (MHT) QUANTITY ON PUFF PASTRY QUALITY WITH CONSTANT RELAXATION TIME (30 MIN) APPLIED