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Investigation of the influence of processing parameters on physicochemical properties of puff pastry margarines using surface response methodology

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ABSTRACT

The influence of some processing parameters on the physicochemical properties of two types of puff pastry margarines (PPM) manufactured at pilot scale was investigated. A Plackett–Burman experimentation design was used to select the processing parameter combinations to test. A pilot-scale line, equipped with a scraped surface heat exchanger (SSHE) and a resting tube, was used to produce the margarines. The considered processing parameters were the "buffer tank" temperature, the flow rate, the SSHE temperature, the scraper blade rotational speed and the resting tube temperature (two levels by parameter). The margarines were stored at 15 °C and 20 °C. The physicochemical properties investigated were the solid fat content (SFC), the dropping point (DP), and the texture (hardness) at these two temperatures. The results were statistically analyzed by the response-surface methodology to find out the processing parameters influence on each physicochemical property. Experimental results confirmed that physical properties of both margarines were strongly influenced by the processing parameters. In this study, whatever the formulation or the physicochemical property analyzed, it was shown that the SSHE temperature, the flow rate and the resting tube temperature were the most frequently significant parameters.

1. Introduction

The functionality of margarines and shortenings as bakery ingredients depends on several factors and is related to the final application of the product (Cavillot et al., 2009). Puff pastry products are made of multiple alternate margarine-dough layers, which are responsible for their appreciated flaky structure (Ghotra, Dyal, & Narine, 2002). Margarines designed for such applications have to possess specific properties in order to make the final product satisfying: to be very firm and to have a good plasticity (Brekke, 1980; Nor Aini & Miskandar, 2007), without being oily (Cavillot et al., 2009). Predetermined plasticity, firmness and solid fat content profile are the main requested properties. They allow the margarine to perform essential functions in the puff pastry preparation, which are mainly to separate the dough layers and to trap water that evaporates in the oven, which leads to an expanded final product. Margarine cannot be absorbed by the dough layers; the fat film has to remain continuous during the rolling process. Consequently, the quality of baked products depends strongly on the quality of the PPM (Gerstenberg, 2000; Pajin et al., 2011; Skogerson, Boutté, Robertson, & Zhang, 2007; Stauffer, 2005). Several fats can be used to deliver the necessary functionality in such products. Butter, lard and tallow were originally used for preparation of puff pastry products. Nowadays vegetable oils have gained interest but most of them have to be transformed to reach the suitable properties. Partial hydrogenation, interesterification and fractionation are common fat modification processes (Dijkstra, 2007; Pajin et al., 2011). Palm oil and its fractions are more and more used as potential substitutes of partially hydrogenated fats (Gerstenberg, 2000; Ghotra et al., 2002; Nesaretnam, 2006; Simovic, Pajin, Seres, & Filipovic, 2009; Sivaruby, Miskandar, Nor Aini, Thaigarajan, & Mohd; Skogerson et al., 2007; Young & Wassell, 2008). However, the use of palm oil in PPM could lead to defects: the margarine becomes lumpy, crumbly, soft and greasy when worked (Duns, 1985; Liu, Meng, Zhang, Shan, & Wang, 2010; Madsen, 1981). In literature several studies show that formulation is a key factor affecting the final product quality, which is not the main subject of this present paper. It is also known that the processing is as critical (Bongers & Almeida-Rivera, 2011; Chrysan, 2005; deMan, deMan, & Blackman, 1989; Faur, 1980; Greenwell, 1981; Miskandar, Man, Yusoff, & Rahman, 2005). A good understanding of the effects of the processing parameters on some important physicochemical properties of PPM could help to overcome this problem.

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To our knowledge, there are only few studies on a pilot scale reported in the literature regarding the process (Miskandar, Che Man, Yusoff, & Rahman, 2002a, 2002b, 2004, Miskandar et al., 2005; Miskandar & Nor Aini, 2006), in which a palm-based margarine formulation was used and a systematical approach was adopted (one parameter by one). The approach here is a global one, which is original. The main goal of this work is to highlight and describe the effects of processing parameters on selected physicochemical properties of PPM. An experimental design (Plackett–Burman) has been used to target the parameter combinations and so optimize the experiments number. The results were analyzed by a response-surface methodology in order to find out the processing effects on margarine properties. In order to compare the processing effects, this approach was applied to two palm-based margarine formulations, differing by their fat phase composition. These two formulations (RP & FPB) are illustrative of the current trend, as cited above.

2. Material and methods

2.1. Material

All fats were industrially supplied: RBD palm oil (Iodine Value, IV = 48.2), palm stearin (IV = 37.6), palm olein (IV = 58.2), partially hydrogenated palm oil (IV = 36.8) and rapeseed oil (IV = 111.6). Other ingredients were water (municipal water supply), NaCl (Everyday, Colruyt, Halle, Belgium), citric acid (Merck, Overijse, Belgique) and Dimodan® (Danisco, Copenhagen, Denmark).

2.2. Experimental methods: pilot production of margarines

The fat phase, representing 80% of the formulation, was composed of 79.3% of fats & oils and ~0.7% of Dimodan® as emulsifier (Table 1). The aqueous phase contained 1% of NaCl and 0.05% of citric acid.

Fats were first melted at 70 °C in a mixing tank with Ekato agitator (Schopfheim, Germany). Emulsifier was dissolved in a small amount of melted fat, then added to the fat phase in the mixing tank. The aqueous phase was prepared by adding salt and citric acid in hot water (70 °C) in a separate tank before being added to the fat phase. Agitation was then set for at least 10 min in order to allow the formation of a good pre-emulsion.

Margarines were processed in a simplified perfector pilot plant (Gerstenberg, Copenhagen, Denmark) made of one cooler tube (a scraped surface heat exchanger, SSHE, cooling surface: 0.075 m^2) followed by a resting tube (2.3 L) (Fig. 1). The modified parameters were the water bath temperature running in the tube exchanger of the second small tank and in the double envelope tube (A, 45 °C or 55 °C), the pump rate of the emulsion (B, 400 or 500 rpm), the blades rotational speed (C, 400 or 500 rpm), the SSHE temperature (D, 15 °C or 20 °C) and the temperature of the water bath running in the double envelop of the resting tube (E, 15 °C or 20 °C).

The produced margarines were collected in plastic containers (100 ml) at the end of the processing line after stabilization of the temperatures. Samples were then split and stored at two temperatures (15 °C and 20 °C) for one and three weeks before analysis.

Table 1
Composition and trans content of the margarines fat phases (% fat phase).

Raw material	Margarine RP (rapeseed) (%)	Margarine FPB (fully palm based) (%)
RBD palm oil	39	40
Palm stearin	28	45
Rapeseed oil	18	–
Partially hydrogenated palm oil	15	–
Palm olein	–	15
Trans content[a]	2.9 ± 0.14	0.5 ± 0

[a] See Cavillot et al. (2009) for analysis method.

2.3. Physicochemical characterization

The solid fat content (SFC), dropping point (DP) as well the hardness (texture) analysis were conducted on margarines stored at 15 °C and 20 °C, after one and three weeks of production.

2.3.1. Solid fat content

The SFC was determined with a pulsed nuclear magnetic resonance (p-NMR) spectrometer (Minispec-mq20, Bruker, Karlsruhe, Germany). Three standards (Bruker, Karlsruhe, Germany) with specific SFC (0.0%; 31.1% and 74.8%) were used for the daily calibration of the apparatus. In order to maintain the physical integrity of the crystallized products, the NMR tubes were filled by using a glass tube with a tight fitting plunge as described by Braipson-Danthine and Deroanne (2004). Then the filled tubes were re-tempered for 30 min at their storage temperature (15 °C or 20 °C) in a thermocirculated water bath before the measurement. Three tubes were prepared for each sample.

2.3.2. Dropping point

DP were measured with a Mettler FP81HT measuring cell equipped with an FP90 central processor (Mettler-Toledo S.A., Zaventem, Belgium). The heating rate was 1 °C/min, after a delay of 180 s. Two measurements were carried out for each sample.

2.3.3. Hardness

The margarines texture measurements were performed at their storage temperature in a controlled temperature room using an SMS TA.XT2i/5 texturometer (Stable Micro Systems, Surrey, U.K.). Penetration tests were carried out with a cone probe (P/45C) penetrating the product (in its container) to a distance of 5 mm at a controlled speed (0.5 mm/s) (Braipson-Danthine & Deroanne, 2004). The maximum penetration force was recorded and expressed in g. Data are reported as average of at least five replicates.

2.4. Experimental design and statistical methods

A Plackett–Burman experimental design was used to highlight the main effects of the process by limiting the number of the experiments, allowing a maximum of information out of a minimum number of experiences. Eight assays (8 sets of parameters) were considered, at 2 levels for each factor (−1 for the lowest value of the parameter and +1 for the highest one), as presented in Table 2.

Statistical data analysis was performed by response-surface methodology using the R software (R foundation, Vienna, Austria). The significance level is 0.05 (p-value). This allows to evaluate the linear influence of each processing parameter on the selected physicochemical properties via a multiple linear regression on the observations. For more details, the reader can refer to Box, Hunter, and Hunter (2005). A separate test was performed for each physicochemical property, at 15 °C and 20 °C, after 1 and 3 weeks of storage. Moreover, in order to estimate the significance of the properties change from week 1 to week 3, a T-test for equality of means was realized (p-value = 0.05).