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Effect of soy flour and whey protein concentrate on cookie color

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ABSTRACT

The objective of this work was to investigate the effect of soy flour and whey protein concentrate (WPC) addition on the extent of Maillard reaction and caramelization during cookie baking. Wheat flour from a rotary molded cookie formulation was partially replaced by full fat soy flour and whey protein concentrate. A central composite design was used and second order models were employed to generate response surfaces for loss of available lysine and for color development. Diffuse reflectance measurement of cookies was used to obtain the k/s coefficients of the Kubelka–Munk equation where k is the absorption coefficient and s is the scattering coefficient at 450, 557 and 680 nm. Luminance, dominant wavelength and excitation purity were also calculated. The addition of WPC produced an important increase in available lysine loss, k/s values and excitation purity, and a decrease in luminance and dominant wavelength. These results indicate that the addition of WPC favors the development of cookie color probably because of its high lactose content. On the contrary, the increment of water content produces a delay of Maillard reaction and caramelization. Soy flour had no significant effect on loss of available lysine and its effect on color parameter was much less significant than that of WPC.

1. Introduction

Cookies prepared from composite flours have been extensively used as protein fortification vehicles due to their long shelf-life and high acceptability (Tsen, Peters, Schaffer, & Hoover, 1973; Warren, Hnat, & Michnowski, 1983). The aim of protein fortification is to develop products with both enhanced protein content and quality, and good sensory acceptance. An important step in the development of composite flour products is the evaluation of the influence of composite flour ingredients on the product's nutritional, sensory and technological attributes (Chevallier, Della Valle, Colonia, Broyart, & Trysman, 2002; Soto-Mendivil & Vidal-Quintanar, 2001). Maillard reaction plays a major role in the cookie manufacturing process. On the one hand, the color and flavors developed during the last steps of Maillard reaction contribute to the acceptability of cookies and other baked products. On the other hand, it has been established that the condensation reaction between reducing sugars and the amino side-chain of lysine during Maillard reaction leads to a severe loss of lysine availability. Color development during cookie baking can be quantified using optical parameters obtained by measuring the diffuse reflectance (Broyart, Trysman, & Duquenoy, 1998; Gómez, Ruiz-París, & Oliete, 2011; Hadiyanto, van Straten, Boom, van Boxtel, & Esveld, 2008; Kane, Lyon, Swanson, & Savage, 2003; Yang, Song, Chen, & Zou, 2011).

The diffuse reflectance of an "infinitely thick" sample can be related to the absorption-scattering ratio coefficient k/s through the Kubelka–Munk equation: $k/s = R\infty/(1 - R\infty)^2$ where k is the absorption coefficient and s is the scattering coefficient. The k coefficient is related to the presence of chromophores that absorb light at the measured wavelength, while s depends on certain physical properties of the sample. The self-backing reflectance $R\infty$ can be obtained by increasing the sample thickness until no changes are appreciated in reflectance measures. Under this condition, the backing is negligible and the incident light is not transmitted but internally reflected by the sample (Pauletti, Matta, & Rozycki, 1999). If the scattering coefficient s is assumed to remain constant, the k/s coefficient is approximately linear with respect to the chromophore concentration. Diffuse reflectance measures also permit to calculate lightness (closely equivalent to luminance), dominant wavelength and excitation purity.

Chevallier et al. (2002) found that the lightness of cookies increases during the first part of the baking process and decreases in a following step. Broyart et al. (1998) showed that lightness variation during baking follows a second-order kinetics influenced by temperature and moisture. Singh and Mohamed (2007) found that the addition of soy protein isolate and vital gluten produced cookies with lower lightness and hue angle values and increased saturation.

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In a previous study, Pérez, Osella, de la Torre, and Sánchez (2008) recommended that an optimal quality of the cookies was achieved when they were made with 13 g/100 g soybean flour, 3 g/100 g whey protein concentrate and 23 g/100 g water in the formulation. Therefore, the objective of this study was to develop statistical models to evaluate the effect of the addition of soy flour and whey protein concentrate in protein-fortified cookies, and measuring the loss of available lysine and the parameters associated to color development.

2. Materials and methods

2.1. Materials

Wheat flour, suitable for industrial breadmaking and with the following characteristics: moisture 13.3 g/100 g, protein 12.1 g/100 g (N × 5.7) and available lysine 2.74 g/100 g protein, was provided by Molinos Matilde Santa Fe (Argentina). Physical properties at Brabender farinograph were: water absorption 59.5 g/100 g, development 2 min, stability 5.2 min and softening 50 Brabender units (BU); and physical properties at Chopin alveograph were: deformation energy (W) = 230 J × 10^{-4} and tensile strength/extensibility (*P*/*L*) ratio = 1.13. Soy flour with moisture 8.9 g/100 g, protein 35.1 g/100 g (N × 6.25), fat 17.6 g/100 g and available lysine 6.38 g/100 g protein was from Atilio Betella y Cía, Santa Fe, Argentina. Whey protein concentrate (WPC) with moisture 4.1 g/100 g, protein 41.2 g/100 g (N × 6.38), lactose 45 g/100 g and available lysine 8.17 g/100 g protein was from Milkaut, Santa Fe, Argentina. The fat used in the recipe was OPTIMA oleomargarine (melting point 36 °C) from CALSA S.A., Buenos Aires, Argentina, and the dried whole egg, from Compañía Avícola S.A., Santa Fe, Argentina. Sodium bicarbonate and ammonium bicarbonate, both supplied by Nutring S.A, Buenos Aires, were used as additives.

2.2. Manufacture of cookies

Cookies were manufactured according to the rotary-molded formula proposed by Gaines and Tsen (1980), with minor modifications to adapt it to a pilot plant conditions. The base formulation was: wheat flour (200 g), sucrose (68 g), oleomargarine (45 g), dried whole egg (10 g), sodium bicarbonate (1 g), ammonium bicarbonate (1 g) and variable water. The wheat flour was partially replaced by soy flour and whey protein concentrate.

All solid ingredients were placed in a Do-Coder Brabender farinograph and mixed during 5 min at 30 rpm. Ammonium bicarbonate and sodium bicarbonate were previously dissolved in water. After mixing, the dough was rolled on a wood table with two 2 mm aluminum strips at both sides and then it was allowed to rest for 1 min. The dough was cut with a 6 cm diameter mold. The pieces were then placed on a cookie sheet lubricated with shortening and baked in a rotary oven without steam at 220 °C during 8 min. After baked, cookies were allowed to reach room temperature, removed from the baking sheet, packaged in polypropylene bags with a moisture of 5–6 g/100 g, and heat-sealed. All samples were then stored at room temperature and protected from light.

2.3. Loss of available lysine determination

Protein content of cookies and ingredients was determined using a LECO FP-328 nitrogen analyzer. Available lysine was analyzed following Carpenter's method modified by Booth (1971). Loss of available lysine was calculated according to the following formula: ALL = 100 × (Li − Lf)/Li, where ALL is the available lysine loss expressed as percentage, Lf is the final content of available lysine for every 16 g of nitrogen and Li is the initial available lysine content for 16 g of nitrogen calculated from the available lysine contribution of each ingredient.

2.4. Color evaluation

The diffuse reflectance of cookies was evaluated using a Karl Zeiss Elrephomat DFC 5 reflectometer with diffused illumination, 10° geometry and D65 illuminant (CIE 1964 standard). The instrument was calibrated with a Zeiss dark standard and Merck barium sulfate for 450, 557 and 680 nm wavelengths. Ultraviolet radiation emitted by the illuminant was blocked using a UV cut filter in order to prevent interference from fluorescent compounds. Each 16 cookie sample was divided into 4 sub-samples of 4 cookies. Four measures were taken from each sub-sample by changing the position of the cookies. Diffuse reflectance was measured with three filters, corresponding to the three wavelengths mentioned before. The results were used to calculate the *k*/*s* coefficient for the three wavelengths using the Kubelka–Munk relation as well as the Luminance (*L*), Excitation Purity (EP) and Dominant Wavelength (DWL). EP and DWL were calculated using an algorithm based on the approximately linear behavior of the Spectrum Locus CIE in the range of 540–600 nm.

2.5. Experimental design

Eight responses were measured: available lysine loss (ALL), *k*/*s* coefficient for three color filters (*k*/*s* 680, *k*/*s* 557, *k*/*s* 450), Luminance (*L*), Dominant Wavelength (DWL) and Excitation Purity (EP). Soy flour (SF), whey protein concentrate (WPC) and water (W) were chosen as variables, considering the mix wheat flour–soy flour–WPC as the 100% base. Table 1 shows the variables and their levels. The values of variables were established according to a central composite design composed of a complete factorial design 2^3, six axial points and six replicates of the central point (Ramandi, Najafi, Raofie, & Ghasemi, 2011). The range for soy flour and WPC was 0–15 g/100 g, while the one for water content was 17.45 g/100 g–27.55 g/100 g. The three factors were coded according to the equation (1):

$$X_1 = 2 \times (\mathrm{SF} - 7.5)/8.92 \quad X_2 = 2 \times (\mathrm{WPC} - 7.5)/8.92$$
$$X_3 = 2 \times (\mathrm{W} - 22.5)/6 \qquad (1)$$

2.6. Statistical analysis

A software package (STATGRAPHICS) was used to fit second order models and generate response surface plots. The model proposed for each response is given by the equation (2).

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 \qquad (2)$$

where b_0 is the value of the fitted response at the central point of the design [point (0,0)]; b_1, b_2 and b_3 are linear regression terms; b_{11}, b_{22} and b_{33} are quadratic regression terms; b_{12}, b_{13} and b_{23} are the cross-product regression terms.

Table 1
Variables and their levels for central composite design.

Variable g/100 g	Symbol	Coded variable levels				
		1.68179	1	0	−1	−1.68179
Soy flour	X_1	15	11.96	7.5	3.04	0
WPC	X_2	15	11.96	7.5	3.04	0
Water	X_3	27.55	25.5	22.5	19.5	17.45