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Effects of inulin and canistel addition in the physical characteristics of fat-reduced processed cheese

Efeitos da adição de inulina e canistel nas características físicas de queijo processado com teor de gordura reduzido

Efectos de la adición de inulina y canistel sobre las características físicas del queso fundido con contenido reducido de grasa

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Abstract

Processed cheese is characterized as a homogeneous mixture, formed mainly by protein and fat, which directly influence its texture. When using fat substitute ingredients, such as hydrocolloids, it is important to evaluate their effect on the physical properties of the final product. The inulin was used as a fat substitute, and canistel, an exotic fruit, as a natural dye and source of bioactive compounds, with the aim of developing processed cheese reduced in fat by 50% (R50) and 100% (R100) and evaluate the effect of this reduction on rheological and texture properties compared to a Standard (S) formulation. Carotenoid content, color, texture and dynamic rheological properties (frequency and temperature scanning) were evaluated. Fat-reduced processed cheeses showed a yellowish color, an increase of more than 10x in the carotenoid content and hardness value reduction in relation to the S. All formulations demonstrated the viscoelastic behavior and the elastic properties were predominant throughout the temperature sweep, mainly for the R50, showing greater stability. The use of inulin and canistel in a product with reduced fat has potential for the food industry, since the first maintains the physical characteristics of the product while the second, increases the content of bioactive compounds and gives natural coloring.

Keywords: Natural dye; Carotenoids; Fat replacement; Texture profile; Rheology.

Resumo

O queijo processado é caracterizado como uma mistura homogênea, formada principalmente por proteína e gordura, que influenciam diretamente em sua textura. Ao utilizar ingredientes substitutos de gordura, como os hidrocoloides, é importante avaliar seu efeito nas propriedades físicas do produto final. A inulina foi utilizada como substituto de gordura, e canistel, uma fruta exótica, como um corante natural e fonte de compostos bioativos, com o objetivo de desenvolver queijo processado reduzido de gordura em 50% (R50) e 100% (R100) e avaliar o efeito dessa redução nas propriedades reológicas e de textura em comparação com uma formulação Padrão (P). Teor de carotenoides, coloração, textura e propriedades reológicas dinâmicas (varredura de frequência e temperatura) foram avaliados. Os queijos processados reduzidos de gordura apresentaram cor amarelada, aumento superior a

10x no teor de carotenoides e redução do valor de dureza em relação à P. Todas as formulações demonstraram o comportamento viscoelástico e as propriedades elásticas foram predominantes em toda a varredura de temperatura, principalmente para o R50, demonstrando maior estabilidade. O uso de inulina e canistel em produto com redução de gordura tem potencial para a indústria de alimentos, pois o primeiro mantém as características físicas do produto enquanto o segundo, aumenta o teor de compostos bioativos e confere coloração natural.

Palavras-chave: Corante natural; Carotenoides; Substituição de gordura; Textura; Reologia.

Resumen

El queso fundido se caracteriza por ser una mezcla homogénea, formada principalmente por proteínas y grasas, que influyen directamente en su textura. Cuando se utilizan ingredientes que sustituyen a las grasas, como los hidrocoloides, es importante evaluar su efecto sobre las propiedades físicas del producto final. Como sustituto de grasas se utilizó inulina, y canistel, una fruta exótica, como colorante natural y fuente de compuestos bioactivos, con el objetivo de desarrollar queso fundido reducido en un 50% (R50) y 100% (R100) y evaluar el efecto de esta reducción en las propiedades reológicas y de textura en comparación con una formulación estándar (E). Se evaluó el contenido de carotenoides, color, textura y propiedades reológicas dinámicas (barrido de frecuencia y temperatura). Los quesos elaborados reducidos en grasa mostraron un color amarillento, un aumento en el contenido de carotenoides y una reducción en el valor de dureza en relación a estándar. Todas las formulaciones demostraron el comportamiento viscoelástico y las propiedades elásticas fueron predominantes durante todo el barrido de temperatura, principalmente para el R50, mostrando mayor estabilidad. El uso de inulina y canistel en un producto con grasa reducida tiene potencial para la industria alimentaria, ya que el primero mantiene las características físicas del producto mientras que el segundo, aumenta el contenido de compuestos bioactivos y le da coloración natural.

Palabras clave: Colorante natural; Carotenoides; Reposición de grasas; Perfil de textura; Reología.

1. Introduction

Processed cheese is a stable oil-in-water emulsions made from cheese, fat, water, melting salt and other ingredients (dairy and nondairy). It is prepared by heating the mass and ingredients to obtain a homogeneous mixture, characterized as a protein-fat concentrate

(Lazaridis & Rosenau, 1980; Hosseini-Parvar, Matia-Merino, & Golding, 2015). Processed cheese is a high consumption dairy product worldwide; however, it has a high fat content when compared to other dairy products.

The association of diseases occurrence with poor diet has increased the concern of consumers in relation to composition of food (as the high content fat, sugar and sodium), especially processed foods, then, foods with fat reduction and/or addition of substitutes capable of performing functions similar to fat have been developed (Cruz et al., 2020; El-Assar, Abou-Dawood, Sakr, & Younis, 2019; Ibáñez, Waldron, & McSweeney, 2016; Khanal et al., 2018; Nguyen, Kravchuk, Bhandari, & Prakash, 2017; Solowiej et al., 2015). As fat plays a key role in foods texture (Khanal et al., 2018; Hosseini-Parvar et al., 2015), low-fat food need to have similar or better properties than products already accepted by consumers. Inulin is a carbohydrate with neutral or slightly sweet taste. It is a soluble fraction of fiber, produced commercially mainly from chicory roots, is considered a prebiotic ingredient, reaching the colon practically intact, favoring the growth of beneficial microorganisms in intestine, reducing the activity of pathogenic microorganisms (Shoaib et al., 2016). Inulin is widely used in functional foods, especially in dairy products. When used in low concentration in foods, maintain the rheological properties and sensory quality of the product (Kalyani Nair, Kharb, & Thompkinson, 2010).

As a fat substitute, inulin has been used in different products, such as: cake (Majzoobi, Mohammadi, Mesbahi, & Farahnaky, 2018); processed cheese analogues (Solowiej et al., 2015); shortbread cookies (Giarnetti, Paradiso, Caponio, Summo, & Pasqualone, 2015); dough and biscuit (Krystyjan, Gumul, Ziobro, & Sikora, 2015); cheese (Karimi, Azizi, Ghasemlou, & Vaziri, 2015); ice cream (Tiwari, Sharma, Kumar, & Kaur, 2014; Akalin et al., 2008), and pork meatballs (Flaczyk, Gorecka, Kobus, & Szymandera-Buszka, 2009).

In addition to fat-reduced foods, the search for functional foods has also increased, these foods in addition to the basic nutrition function, can bring health benefits to consumers (Gul, Singh, & Jabeen, 2016). The canistel (*Pouteria campechiana* (Kunth) Baehni) is an exotic fruit native from Mexico and belonging to the family Sapotaceae (Pushpakumara, Gunasena, & Singh, 2007), is rich in carotenoids from the group of xanthophylls, presents violaxanthin, neoxanthin, zeaxanthin, β-cryptoxanthin and other carotenoids that give the fruit an intense yellow color and antioxidant properties (de Lanerolle, Priyadarshani, Sumithraarachchi, & Jansz, 2008; Murillo, Meléndez-Martínez, & Portugal, 2010).

Exotic fruits can also be used by the food industry as raw materials for the development of natural food additives such as antioxidants, antimicrobials, dyes, flavorings and thickening agents presenting great potential for use in the food (Ayala-Zavala et al., 2011). The objective of this study was to analyze the physical characteristics (texture and rheological properties) of fat-reduced cheese and evaluated the effect of canistel, a new food ingredient, as a source of bioactive compounds and natural pigments.

2. Methodology

2.1 Materials and reagents

The processed cheese ingredients (cheese curd and butter) were purchased from local market-place (Maringa, Parana, Brazil). *Pouteria campechiana* (canistel) was obtained from Bebedouro Experimental Citrus Station (Bebedouro, Sao Paulo, Brazil). The canistel powder was obtained after sanitization, drying (70 °C for 7 h), grind, size standardization with 60 mesh; its composition had 4.76% moisture, 6.48% protein, 9.17% fat, 1.78% ash, 77.81% carbohydrates and 0.88 µg/g carotenoids (dry matter basis). The inulin used was from chicory root fiber, a white and granular powder (Orafti® GR). All other chemical reagents were of analytical grade.

2.2 Processed cheese production

The Standard formulation (S) was elaborated with 19.25% of butter (with 83% of fat), and the other formulations were reduced by 50% (R50) and 100% (R100) of fat in relation to S (Table 1), these formulations were developed from preliminary tests. The inulin (0.5%) and powder canistel (3.0%) addition was the same for all formulations with fat reduction. For S production, the cheese curd (53.99% moisture, 3.57% ash, 21.35% protein, 13.66% fat and 7.44% carbohydrates) was homogenized with water, butter, and melting salt at 90 °C for 4 min. In the fat-reduced processed cheeses, the cheese curd, water, butter, and melting salt were homogenized at 90 °C, and the inulin and canistel were added after 1.5 and 2.0 min respectively. The mixture was heated and homogenized until 4 min. All formulations were stored 24 h at 4 °C before analyzes.

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Table 1. Processed cheese formulations.

Ingredients (g/100g processed cheese)						
	Cheese curd	Emulsifying salt	Butter	Water	Inulin	Canistel
S	51.40	1.04	19.25	28.31	-	-
R50	51.40	1.04	9.62	34.44	0.50	3.00
R100	51.40	1.04	-	44.06	0.50	3.00

S: standard processed cheese; R50: 50% butter fat reduction; R100: 100% butter fat reduction.
Source: Authors.

2.3 Total carotenoids content

Total carotenoids were determined by the method of Rodriguez-Amaya & Kimura (2004). The samples (1 g) and cold acetone (50 mL) was used in successive extractions with homogenization and filtration steps; until solid retained was no more perception of carotenoid characteristic color. All filtrate was mix with petroleum ether (30 mL) and distilled water was added until obtain a clear aqueous phase. Ethereal solution was mixture with petroleum ether (50 mL) and the absorbance read in a spectrophotometer (Evolution™ 300, Thermo Fisher Scientific, UK) at 450 nm. The total carotenoid content (µg β-carotene equivalent.100g-1) was calculated from Equation 1.

$$\text{Carotenoids content} = (\text{Abs} * V * 10)/(\text{SW} * \varepsilon) \quad (1)$$

Abs= absorbance

V= final volume of extract (mL)

SW= sample weight (g)

Ɛ= 2592 (Absorption coefficient of β-carotene in petroleum ether).

2.4 Color evaluation

Color was measured by the CIELAB system using a colorimeter (Chroma Meter CR-400; Minolta, Mahwah, New Jersey, USA) using illuminant D65 and 10° observer.

2.5 Texture profile analysis

Texture profile analysis (TPA) was performed by a texture analyzer CT-III (Brookfield, Middleborough, USA). The processed cheeses (40 mL) were evaluated at 10 °C by acrylic cylindrical probe TA4/1000 (38.1 mm of diameter) with Trigger of 8 g, and test speed of 2 mm/s. It was evaluated the hardness (g), adhesiveness (J), elasticity (mm), and gumminess (g) parameters.

2.6 Rheological properties

The dynamic rheological properties were performed in the S, R50, and R100 formulations at 10 ± 0.1 °C using a controlled stress rheometer Mars II (Haake®, Thermo Fisher Scientific Inc., Newington, Germany) fitted with a 35 mm diameter cone-plate with a gap of 0.052 mm (Souza Ferreira et al., 2017). Samples were applied to the lower plate and allowed to equilibrate for 1 min before analysis. After determination of the linear viscoelastic region for each formulation, frequency sweep analysis was performed from 0.1 to 10.0 Hz at a constant stress of 100 mPa. The temperature sweep analysis also was performed at 1.0 Hz between 25 °C and 60 °C with a heating rate of 3 °C min-1. The storage modulus (G') and loss modulus (G″) were then calculated using RheoWin 4.10.0000 (HaakeR) software. The dynamic rheological properties of five samples from each formulation (S, R50 and R100) were determined.

2.7 Statistical analysis

The data were evaluated by analysis of variance using the general linear model (GLM) with in SPSS (v.15.0) (IBM SPSS Statistics, SPSS Inc., Chicago, USA) for Windows. Data are presented as mean and standard deviation. The experiment was repeated three times with two replicates per treatment. Significant differences were observed, Tukey test with statistical significance set at P = 0.05.

3. Results and Discussion

3.1 Color and total carotenoids content

The canistel addition was able to provide bioactive compounds to processed cheese, as the carotenoids (Table 2), widely found natural and lipophilic pigments (fruits, vegetables, leaves of plants), responsible for red, yellow, orange and pink coloration of many foods (Elvira-Torales, Garcia-Alonso, & Periago-Castón, 2019).

Table 2. Carotenoids content and color evaluation of standard (S) and fat-reduced processed cheeses formulations.

	Carotenoids (μg β-carotene/100g)	L*	a*	b*
S	0.40 ± 0.00[c]	87.79 ± 0.49[a]	-4.21 ± 0.17[b]	19.01 ± 0.90[b]
R50	4.10 ± 0.00[b]	78.14 ± 0.25[b]	-2.46 ± 0.18[a]	34.29 ± 0.02[a]
R100	5.20 ± 0.01[a]	75.21 ± 0.29[c]	-2.55 ± 0.40[a]	34.75 ± 0.07[a]

Means with different lowercase letters in the same column are significantly different ($p<0.05$). Results are expressed as mean ± standard deviation. S: standard processed cheese; R50: 50% butter fat reduction; R100: 100% butter fat reduction. Source: Authors.

The increase in carotenoid content was over 10x compared to S, in fat-reduced formulations. The enrichment of cheeses processed with carotenoids is another way of ingesting these compounds in the consumer's daily diet. Its benefits have already been studied (Eggersdorfer & Wyss, 2018; Rao & Rao, 2007; Perera & Yen, 2007), such as the prevention of diseases such as cancer (Wan et al., 2014), performance in the cognitive functions of the brain (Walk et al., 2017), fertilization (Mínguez-Alarcón et al., 2012), immunological modulation (Jonasson, Wikby, & Olsson, 2003), that is, maintaining good health, so it is important to increase forms of consumption of these compounds, since human beings cannot synthesize carotenoids and must ingest them in food.

The addition of canistel powder to the processed cheese make the product presenting a yellow coloration (Table 2). As showed by b* (-, blue; +, yellow) and a* (-, green; +, red) parameters increase and L* (0, black; 100, white) decreased according to the fat reduction in the formulations ($p<0.05$). Light-colored products, such as processed cheese, can become more attractive for consumers with the use of natural dyes which, in addition to coloring, can add beneficial health effects.

3.2 Texture profile evaluation

In the TPA, the S formulation presented high value ($p<0.05$) for all parameters (Table 3). The hardness decreased according to the fat reduction and all treatments presented significant differences. The hardness represents the maximum force during the first compression of the sample, and this force may reduce when protein-protein interactions weaken. When the hardness values decrease together with an increase of moisture, the hydration of the protein matrix may occur, making the product softer (Hennelly, Dunne, O'Sullivan, & O'Riordan, 2005).

Table 3. Texture profile analyze (TPA) of standard (S) and fat-reduced processed cheeses formulations.

	Hardness (g)	Adhesiveness (mJ)	Elasticity (mm)	Gumminess (g)
S	3256.67 ± 168.62[a]	88.83 ± 16.54[a]	27.54 ± 2.82[a]	2415.67 ± 91.31[a]
R50	2198.33 ± 77.67[b]	41.27 ± 2.49[b]	19.59 ± 2.61[b]	1777.67 ± 183.75[b]
R100	588.33 ± 16.07[c]	18.97 ± 1.33[c]	10.65 ± 1.13[c]	510.00 ± 19.92[c]

Means with different lowercase letters in the same column are significantly different ($p<0.05$). Results are expressed as mean ± standard deviation. S: standard processed cheese; R50: 50% butter fat reduction; R100: 100% butter fat reduction. Source: Authors.

Fat replacement by inulin with addition of whey protein also decreased hardness and adhesiveness of analogues processed cheeses (Sołowiej et al., 2015). The adhesiveness was reduced with the fat replacement, demonstrating that the lower the adhesion, the lower the resistance of the product to be removed from a package after contact, and the lower the resistance to spread the product, which are important characteristics at the moment of consumption (Sołowiej, 2012).

3.3 Rheological property measurements

3.3.1 Frequency sweeps

The processed cheeses formulations (S, R50 and R100) presented the same behavior in the dynamic rheological measurements at 10 °C (Figure 1). The G’ (storage modulus) and G’’ (loss modulus) demonstrate the viscoelastic behavior of the system (Mleko & Foegeding, 2000).

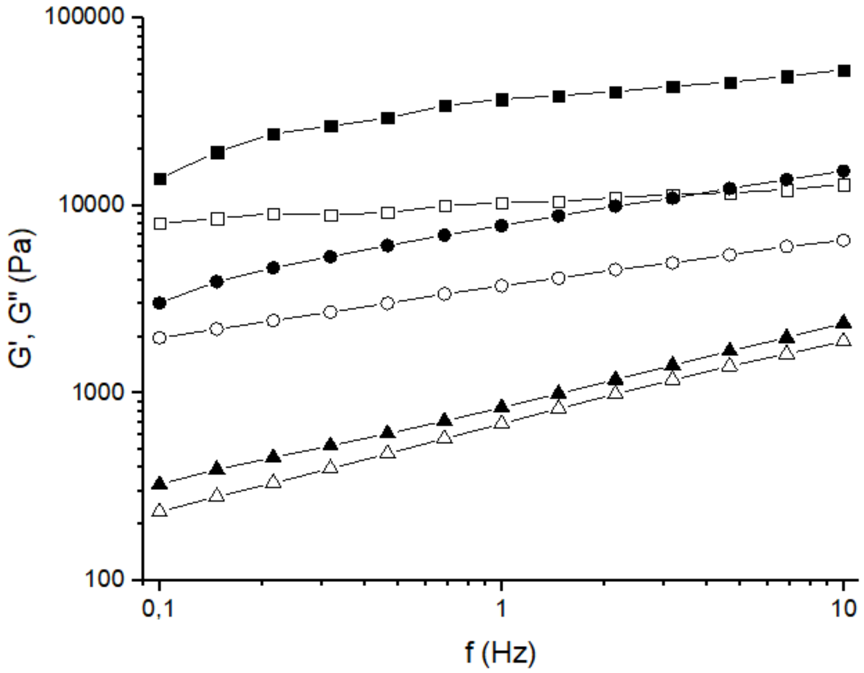

Figure 1. The storage (G') (solid symbols) and loss (G") (open symbols) module of standard (S) and fat-reduced processed cheeses formulations added of canistel and inulin (R50 and R100) during frequency sweep test (0-10 Hz) at 10 °C. S: standard processed cheese (■,□), R50: 50% butter fat reduction (●,○), R100: 100% butter fat reduction (▲,△). Source: Authors.

Formulations S and R50 showed the same behavior, a small and regular increase during the frequency increasing, demonstrating more stability than R100. All formulations demonstrated the viscoelastic properties, G' are greater than G'' during the frequency sweep. Higher G' and G" values were obtained for S formulation, since for formulations with reduced fat, lower G' is expected (Ma & Barbosa-Cánovas, 1995). G' greater than G" show the solid character of all formulations, mainly for S, with higher values, showing a strong gel and recoverable deformations. This relation also was showed by texture analysis (Table 3), in which formulation S had the highest hardness value.

3.3.2 Temperature sweeps

The effect of heating in the G' and G" of processed cheese formulations were shown in Figure 2. The G' was greater than G" for all formulations, again demonstrating their viscoelastic flow behavior.

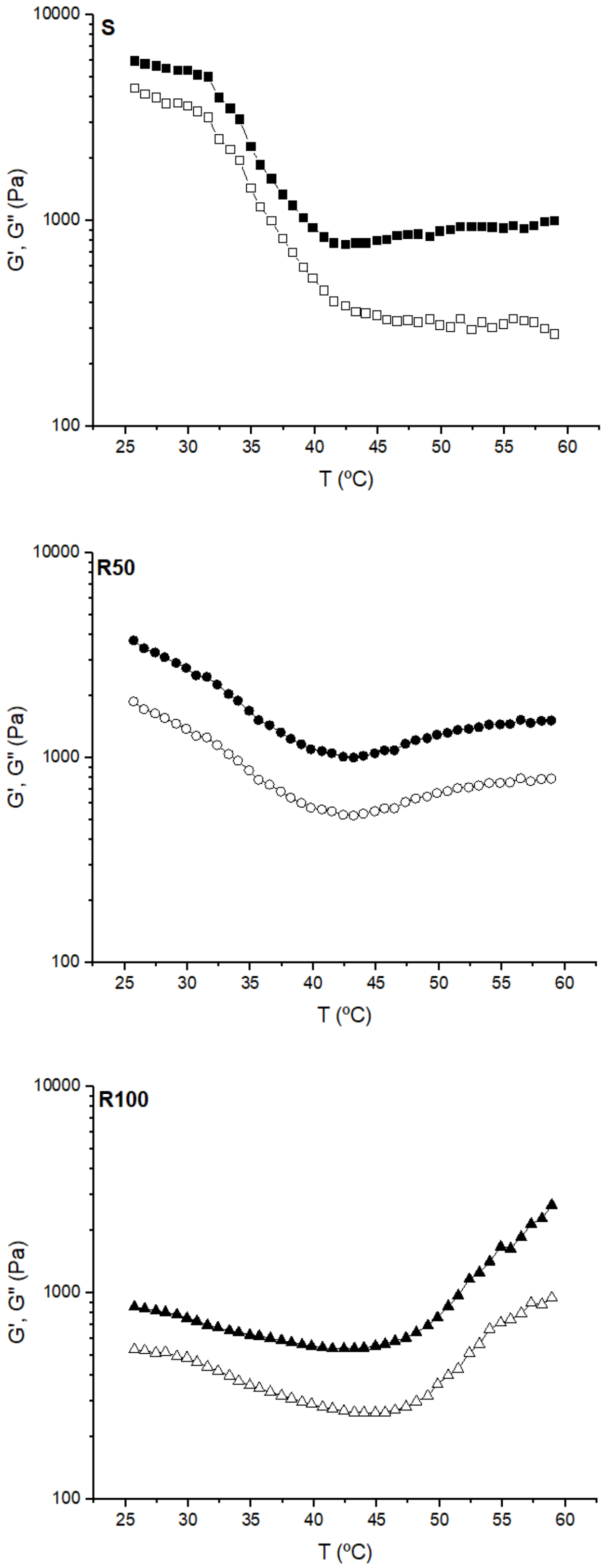

Figure 2. The storage (G’) (solid symbols) and loss (G”) (open symbols) module of standard (S) and fat-reduced processed cheeses formulations added of canistel and inulin (R50 and R100) during temperature sweep (25- 60 °C). Source: Authors.

A decrease in the values of G' and G" was observed in the first phase of the heat treatment, up to approximately 43 °C in all processed cheese formulations, indicating that the gel structure has been weakened due to decreased protein-protein interactions in the network of casein during the melting and deformation of softened fat globules (Hennelly et al., 2006), resulting in a less elastic system (Sołowiej et al., 2015). From that temperature, formulation S showed a slight increase in G 'while G ″ decreased, pointing to a reduction in viscous behavior and an increase in elasticity at higher temperatures. While for R50, G' and G" showed the same behavior, showing an increase in elastic behavior.

However, for R100 there was a sharp increase in the values of G' and G" from 45 °C, demonstrating a solidification of the cheese matrix at higher temperatures, which was also observed by Hennelly et al. (2006) at 55 °C for cheese processed with inulin. During heating and melting of the cheese sample, inulin is able to bind to free water, which increases inulin concentrations (properties of the gel) and slows down the flow (Sołowiej et al., 2015).

In all formulations, the elastic behavior prevailed in the samples during heating, and the values of G' and G" of the formulations with fat reduction were lower in relation to S, as also observed by Sołowiej et al., (2015) with partial replacement of anhydrous milk fat by 1, 2 or 3% inulin.

4. Conclusions

The canistel and inulin addition in fat-reduced processed cheese making it a softer and stable product, same a 50% reduction in fat, the elastic behavior of processed cheese was stable during heating. The natural pigments modified the color of processed cheese, coffering a yellow color and increasing the carotenoids content. The canistel and inulin addition to processed products with fat-reduced content has potential for the food industry, since the first assists in maintains the physical characteristics of the product while the second in addition to giving natural coloring, increases the number of bioactive compounds in the product.

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