

Native black Michuñe potato variety: characterization, frying conditions and sensory evaluation

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SUMMARY. The aim of this study was to evaluate the chemical and nutritional composition, to establish frying processing conditions and to determine the sensory profile and acceptability of Black Michuñe (BM) potato chips. BM had a higher protein content, half the ether extract content and nitrogen-free extract, a lower caloric intake (70 kcal/100g) and amylose content (17.5%) than Desirée (DES). To set the frying conditions, the Taguchi method was applied using a matrix design L_9 ($3^2, 2^2$). The variables studied were: temperature, time, potato variety (raw material) and pretreatment. The responses evaluated were: the color difference as well as the content of reducing sugars and total polyphenols. The best frying conditions were BM with a pretreatment at 160°C for 7 min for color, DES without pretreatment at 140°C for 7 min for reducing sugar content, and BM without pretreatment at 180°C for 4 min for polyphenol content. Then, sensory profiles of potato chips from BM, DES and a commercial package were determined by selecting the descriptors texture, firmness, color, salty taste and oiliness. Significant differences in color and oiliness were found. Finally, the acceptability test was applied to BM potato chips where color (64%) was the only attribute not as accepted as texture (95%), salty taste (87%) and product (97.3%). This study demonstrated that BM potato chips have a satisfactory acceptability by consumers

Key words: Black Michuñe potato variety, frying conditions, sensory evaluation.

RESUMEN. Papa nativa variedad Michuñe negra: caracterización, condiciones de fritura y evaluación sensorial.

El presente trabajo tiene por objetivo evaluar la composición química y nutricional de papa Michuñe negro (BM), establecer condiciones de proceso de fritura, determinar el perfil sensorial y aceptabilidad de papas fritas chips. BM presentó un mayor contenido proteico, la mitad de extracto etéreo y extracto libre de nitrógeno, una menor ingesta calórica (70 kcal/100g) y un menor contenido de amilosa (17,5%) comparada con la variedad Desirée (DES). Para establecer condiciones de fritura se utilizó metodología Taguchi empleando una matriz de diseño L_9 ($3^2, 2^2$). Las variables seleccionadas fueron: temperatura, tiempo, variedad de papa (materia prima) y pretratamiento. Las respuestas evaluadas fueron: diferencia de color, contenido de azúcares reductores y polifenoles totales. Las mejores condiciones de fritura fueron: BM con pretratamiento a 160°C por 7 min para color, DES sin pretratamiento a 140°C por 7 min para azúcares reductores y BM sin pretratamiento a 180°C por 4 min para polifenoles totales. Luego, los perfiles sensoriales de las papas chips de BM, DES y comercial fueron determinados seleccionando los descriptores textura, firmeza, sabor salado y aceitoso. Se encontraron diferencias significativas en los descriptores color y aceitoso. El color (64%) fue el único atributo que obtuvo un nivel de aceptación más bajo entre los otros como textura (95%), sabor salado (87%) y producto (97.3%). Este estudio demostró que los chips de BM fueron satisfactoriamente aceptados por los consumidores.

Palabras clave: Variedad papa Michuñe negro, condiciones de fritura, evaluación sensorial.

INTRODUCTION

In Chile, potato is the country's fourth most important crop and a dietary staple (1). The Isla Grande de Chiloé, located in the southern part of Los Lagos Region, is considered one of the sub-centers of origin for potato due to the many findings of native varieties, which were very useful for creating new potato varieties (2). Native potato tubers show a wide variability in tuber shape, flesh and skin color, texture, sizes, fla-

vor, and phenological characteristics (3). They have recognized attributes of flavor and red/blue color due to the presence of such antioxidants as anthocyanins, characteristic compounds of vegetal products. Michuñe, Guadacho, Lobo, Murta, Pachaconas are native varieties, among many others. In addition, a wide variety of potatoes cultivated in Chile such as Desirée, Yagana, Asterix, Baraka, etc. have been introduced from European countries or North America.

According to Miranda and Aguilera (4), potato chips and derivatives represent 12% of the market in the main products of potato processing. Frying is a widely used method for cooking that creates unique textures and flavors in foods. Among potato sub-products, potato chips are a high consumption food for their characteristics of flavor, aroma, crunchy texture, and increased palatability afforded by the frying process (5).

During frying, the original structure of raw potato undergoes transformations that will determine the quality attributes of the final product such as oil content, crispness, roughness, porosity. In turn, these structural changes depend on the processing conditions of potato prior to being fried and on frying conditions (e.g. pretreatment, temperature, time).

Apart from the sensory benefits of heat treatments like potato frying, it has been shown that these heat processes can also induce undesirable color changes largely produced by the Maillard reaction (6). In this context, it is necessary to control the reaction factors.

Among the different physical properties of foods and food products, color is considered an important visual attribute in the perception quality of a product. Potato chip color is a vital criterion for industrial potato processing and is strictly related to consumer perception. Among the sensory potato attributes highlighting texture, aroma, flavor, color, texture is considered the most important. Several methodologies been used to describe these sensory properties, among which Quantitative Descriptive Analysis is the best known (7, 8, 9), as it provides the sensory profile of a product, assigning intensity values for each selected feature.

The aim of this study was to evaluate the chemical and nutritional composition of the black Michuñe variety, to establish frying process conditions, to contribute to the knowledge of the sensory characteristics of the black Michuñe variety by producing the sensory profile, and to determine the acceptability of potato chips.

MATERIALS AND METHODS

Sample preparation

The native Black Michuñe (BM) from Chiloé,

Chile (Fig 1), the white flesh potato Desirée (DES), and commercial packaged potato chips were used as raw material. The samples were supplied directly from the harvest area located on Chiloé Island. Both the black Michuñe and white-fleshed Desirée potatoes were selected by discarding units with possible phytosanitary problems. The commercial product was purchased in the local market. Then, the selected potatoes were hand-peeled, washed and finely cut with an electric mill AFK Germany Model AS-150 between 2.0 to 3.0 mm thick. For the frying process, an electric fryer fitted with a thermocouple was used.

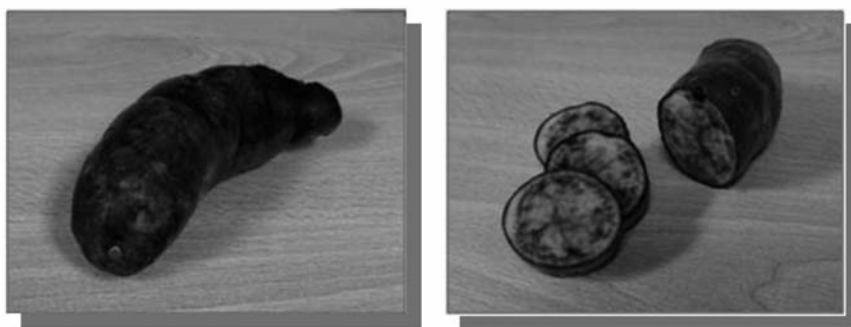


FIGURE 1.
Native black Michuñe potato variety from the Chiloé Island.

Chemical and nutritional analysis

In order to characterize the raw material, a proximal analysis was performed on samples of fresh native potatoes. Moisture, ash, protein, ether extract, crude fiber and nitrogen-free extract were measured in samples of fresh native potato samples according to AOAC standard procedures (10). In order to determine the caloric intake of the black Michuñe potato, the percentage of proteins, carbohydrates and ether extract was calculated using Atwater coefficients.

Determination of amylose and total starch

To determine the amylose content in black Michuñe potato, a megazyme amylose/amylopectin assay procedure utilizing a commercial kit (Megazyme Ireland International, Ltd., Bray, Ireland) was performed according to the manufacturer's recommendations. This method applies a procedure based on the specific precipitation of amylopectin by concanavalin-A lectin. Amylose content is expressed as a percentage of total sample starch. The total starch was determined by measuring the total glucose after digestion with thermostable α -amylase and amyloglucosidase enzymes.

Frying process conditions

Slices of both potato varieties were subjected to an immersion pretreatment in a 1% citric acid solution for 40 minutes in order to reduce enzymatic browning. An electric fryer with commercial sunflower oil was used to perform the chip frying, with a slice:oil ratio of 1:20. The frying temperatures ranged from 140°C to 180°C for 4 and 10 min. These conditions were evaluated applying an experimental design.

Design of experiments

The Taguchi methodology was used, as this can work simultaneously with several control factors. This method uses the so-called orthogonal arrays corresponding to an experimental design, which allows a mathematical evaluation independent of the effect of each factor in the design (11). The independent variables were temperature (T) (140, 160 and 180°C), time (t) (4, 7 and 10 minutes), potato variety (BM and DES) or raw material (RM), and pretreatment (PT) (immersion in citric acid). For this study, a matrix design $L_9(3^2, 2^2)$ was used, where the subscript 9 corresponds to the number of experimental runs and the superscript represents the controlling factors.

The analysis of the quality response averages for each experimental run was carried out for studying the "smaller is better" characteristic for a color change, and "greater is better" for the case of reducing sugars and total polyphenols. The average for level of each factor and the variance analysis were then calculated using Qualitek-4 software. The average magnitude difference of the response for each factor level was determined in order to calculate the inclination slope so as to estimate the impact of each factor on the response and determine the optimal response theoretical equation (OTE). Finally, a confirmatory test was applied.

Color determination

To determine the potato chip color, a crushed sample was spread evenly over a miniplate, placed to capture the image inside a chamber isolated from natural light and analyzed using Adobe Photoshop software to determine the parameters $L^* = L/255$, $a^* = (240a/255) - 120$, $b^* = (240b/255) - 120$, where L: gives a luminance or brightness value of the sample, a: shows the variation area between red and green of the spectrum, b: refers to the variation area between yellow and blue of the spectrum (12).

The color change ΔE was determined from the value $\Delta E^* = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$ (eq. 1)

Determination of reducing sugars

An aqueous extract was obtained using a 2 g sample, which was centrifuged by removing the supernatant containing reducing sugars. A calibration curve was prepared using 20 mg/L glucose as standard. An aliquot of the sample (1 mL) was added to 1 mL of 2,5-dinitrosalicylic acid (DNS) and boiled for 5 min (13). Then the sample was diluted with 5 mL of distilled water and measured in a spectrophotometer (Thermo Genesys model 6) at 540 nm. The samples were run in triplicate.

Determination of total polyphenols

Total phenolic content was determined by its reaction with Folin–Ciocalteu (FC) reagent (Fluka, Japan), according to the method reported by Velioglu et al. (14). Briefly, 200 microliters from the methanolic extract were mixed with 1 mL of Folin–Ciocalteu reagent and 0.8 mL of Na_2CO_3 (60 g/L) (Sigma-Aldrich, Germany) solution was added to the mixture. After heating for 15 min at 45 °C in a water bath (MSH-10 Daih Scientific), the absorbance of samples was measured at 765 nm (Genesys 6, Thermo Scientific, USA). Results were expressed as gallic acid (Sigma-Aldrich, Germany) equivalent per gram of dry matter (mg GAE/g d.m.). The measurement was carried out three times.

Sensory profile

For the sensory sample evaluation, the Quantitative Descriptive Analysis (QDA) was measured using unstructured descriptive analytical scales 85 mm long. The generation of descriptors (texture, firmness, color, salty and oily taste) as well as the manner for evaluating them took place in open panel sessions during the training panel. At the same time, discriminatory capacity was found by assessing their reproducibility. In particular, firmness was determined by manipulating the sample to evaluate whether it maintained its structure or disintegrated easily. With respect to the oily characteristic, the remaining oil residue on the hand was determined.

Consumer acceptability test

To perform the acceptability test, four parameters

were selected: salty taste, color, crunchy texture and product. The acceptability of each parameter was measured by means of the hedonic test (7) using a five-point scale with ends: I dislike it very much and I like it very much. In this trial, eighty-five consumers participated.

Statistical data analysis

The data were analyzed using analysis of variance (ANOVA) and the significant mean difference was determined with Duncan's multiple comparison test ($p \leq 0.05$).

RESULTS

Characterization of black Michuñe potato

The chemical and nutritional composition of the native BM variety was compared with the standard white-fleshed DES potato variety, as shown in Table 1.

From these values, the protein content of the BM (6.8%) highlights that this doubles the protein content of a standard potato, whereas the nitrogen-free extract (NFE) in BM is 10%. This value is less than the standard potato content corresponding to 16% (15). According to these results, the variety from Chiloé Island presented a lower carbohydrate content than the standard potato. In addition, the amylose percentage in BM was slightly lower, reaching 17.5% compared with 22.0% of the DES. The value obtained for energy intake (70 kcal/100g) was lower than the value for a standard potato.

TABLE 1.
Chemical and nutritional composition of black Michuñe and white-fleshed Desirée potatoes.

Parameter (g/100 g)	Black Michuñe potato	White-fleshed Desirée potato
Moisture	77.12	75.33
Ash	4.77	1.10
Proteins	6.86	2.53
Crude fiber	0.68	0.26
Ether extract	0.03	0.06
Nitrogen-free extract	10.54	20.72
Amylose	17.5	22.0
Energy (Kcal/100g)	69.86	93.54

Effect of frying conditions on color change in potato chips

For color, the criterion "less is better" was used, i.e. less color change is the best response. BM with a pretreatment at 160°C for 7 min of frying (design point 5) presented the best frying conditions obtained with a ΔE of 8.18 (Table 2). ANOVA showed that the factors T, t and RM were significant ($p < 0.05$), contributing 87.41% of the variation, where the temperature conditioned the response robustness of 56.26%.

Effect of frying conditions on the reducing sugar content in potato chips

For reducing sugar content, the criterion "more is better" was used. The best frying conditions were obtained using a standard potato without pretreatment at 140°C for 7 min (design point 2) reaching 0.97 mg of glucose/g d.m. (Table 2). The variables T, t and RM significantly affected the response ($p < 0.05$), providing together 95.79% and conditioning the response robustness of 89.65%.

Effect of frying conditions on the polyphenol content in potato chips

For the evaluation of the effect of frying conditions on the polyphenol content in BM and DES potato chips, the criterion "more is better" was used, i.e. higher polyphenol content after the frying process is better. Thus, the best combination of design factors were found in the BM variety without pretreatment at 180°C for 4 min of frying and reached 2.57 mg GAE/g d.m. (design point 7) (Table 2).

ANOVA showed that the RM, T and PT variables were significant ($p < 0.05$) providing together 85.75%. These variables determined a response robustness of 84.61%.

Sensory Profile

In texture and firmness, the samples showed a similar intensity degree without significant differences ($p \leq 0.05$) among the samples (Table 3).

On the subject of firmness, a similarity was observed in results cataloging samples as resistant to manipulation without presenting signs of fragility. The salty taste perception was similar in BM samples and in the commercial product with an appropriate degree of intensity, which differed significantly from the DES variety.

As for the color, values obtained in DES and commercial samples were significantly higher than those found in the BM as both were characterized by a yellow color.

TABLE 2
Orthogonal arrays $L_9 (3^2, 2^2)$ and responses of Color, Reducing Sugar Content and Total Polyphenols obtained for frying processing conditions

Design Point	Independent variables				Color (ΔE)	RSC (mg glucose/g d.m.)	TP (mg GAE/g d.m.)
	T	t	RM	PT			
1	1	1	1	1	9.35±0.12	0.71±0.09	2.15±0.05
2	1	2	2	2	10.36±2.85	0.97±0.01	1.54±0.13
3	1	3	1	1	8.91±1.26	0.64±0.02	1.85±0.05
4	2	1	2	1	13.32±0.91	0.7±0.01	0.61±0.02
5	2	2	1	1	8.18±0.30	0.54±0.01	1.37±0.71
6	2	3	1	2	14.91±2.26	0.27±0.05	2.42±0.17
7	3	1	1	2	13.87±1.06	0.43±0.003	2.57±0.14
8	3	2	1	1	15.65±3.95	0.41±0.02	2.52±0.01
9	3	3	2	1	29.38±1.58	0.42±0.001	1.93±0.09

T: temperature, t: time, RM: Raw Material, PT: Pretreatment RSC: Reducing Sugar Content

TABLE 3
Value averages (mm) of descriptors per sample. Means with different letter (a, b) indicate significant differences between potato varieties, according to the Duncan's test at 0.05 significance.

Descriptor	Black Michuñe variety	Desirée variety	Commercial potato
Texture	78 ^(a)	78 ^(a)	81 ^(a)
Firmness	81 ^(a)	74 ^(a)	72 ^(a)
Salty	69 ^(b)	62 ^(b)	77 ^(a)
Color	22 ^(b)	66 ^(a)	74 ^(a)
Oiliness	12 ^(b)	16 ^(b)	40 ^(a)

The perception of oily potato chips was evident in the three samples, with the presence of residual oil in products of BM and DES varieties being more marked than in the commercial sample.

Acceptability Test

To find out if the variety of BM potato chips gratifies consumer expectations or not, an acceptability test was performed separately analyzing color, texture, salty taste and the product (Fig. 2).

a) Color

The result of the consumer survey was 64% for the sum of the scores: I like it a lot, I like it and I am indifferent, compared with 36% of the ratings made by: I dislike it, I dislike it a lot. This attribute must be taken into account because color is one of the

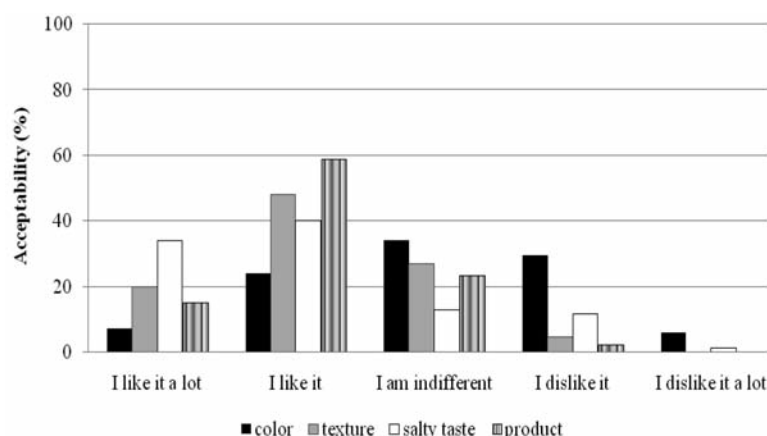


FIGURE 2
Acceptability results of the studied characteristics in black Michuñe potato chip variety.

most important quality parameters valued by consumers in this type of product.

b) Texture

In connection with this descriptor, the results were significantly better for BM potato chips as the acceptability reached 95%.

c) Salty taste

A low percentage of consumers (13%) rejected the product for its salt content, while 87% of consumers accepted it.

d) Product

The BM potato chip was very well accepted by consumers based on several characteristics. Only 2.7% of consumers said they disliked the product compared with 97.3% of favorable responses.

DISCUSSION

The results of the amylose percentage found in BM (17.5%) and DES (22.0%) are similar to those reported in the literature. (16, 17). A high amylose content is supposed to be favorable in foods such as potatoes. The presence of high levels of amylose may enhance the functionality of starch, e.g. its film-forming ability (18, 19). In addition, Hu et al. (20) reported that the amylose/amylopectin ratio is generally 20/80. However, an increased amylose content also increases the resistant starch content, as amylose is not completely digested by digestive enzymes. Therefore, not all carbohydrates rich in amylose are used by the organism. Consequently, an increase in amylose content could contribute to a reduction in the glycemic index.

The value obtained for energy intake was 25% less for BM than for DES. Considering that one of the greatest public health problems nowadays is the obesity caused by an inappropriate diet with an increased intake of high-calorie foods, BM represents a nutritious and healthy alternative that could be incorporated into everyday foods.

The evaluation of the effect of frying conditions on the color change in BM and DES potato chips variety made it possible to obtain the best combination of frying conditions.

The fried potato chip color is an important parameter to be controlled during the transformation process. Fried potatoes with a noticeable color change are the result of the Maillard reaction, which depends on the content of reducing sugars, amino acids or proteins in the surface, on the temperature and on the frying time (21).

The DES potato chip obtained the best response with regard to the effect of frying conditions on the reducing sugar content. This fact should be explained because the black Michuñe potato has a lower initial reducing sugar content and it is therefore also lower after frying.

The reducing sugar content is an important parameter to measure, since this is a precursor to the formation of the Maillard reaction, and a substantive change in the reducing sugars would indicate that the reaction had occurred. A higher content of reducing sugars remaining after frying is better as this indicates that this precursor has not been used during the Maillard reaction.

Polyphenols are secondary metabolites widely

known to have antioxidant activity. Polyphenols processed at high temperatures tend to decrease because some of them are thermolabile. For this reason, it was important in this study to evaluate the total polyphenol content in native potatoes after a frying process. When comparing the total polyphenol content in both potato varieties after the frying process, BM showed the highest value. Vatterm and Shetty (22) observed the increasing polyphenol content in potato chips after the frying process. These authors explained that the polyphenol content increase may be because a high temperature would lead to a pyrolysis of phenolic compounds present in the vegetable cell wall.

The lower values obtained in color of the BM compared with DES and commercial samples could be explained by the chemical composition of potato from Chiloé Island, which has a blue/reddish color due to the polyphenol presence in this variety.

The presence of increased residual oil in BM and DES products compared with the commercial sample may be attributed to the non-commercial frying process for BM and DES. According to the results of the acceptability test, BM was properly accepted by consumers, and color was the only attribute that produced a certain level of rejection.

CONCLUSIONS

Chemical analysis in native BM potato showed differences to standard white-fleshed potato DES, mainly in the protein content and NFE. In the blue BM variety, potato chips were obtained with less of a color change, a lower reducing sugar content and a higher polyphenol content, where the potato variety, temperature and frying time significantly influenced the responses ($p < 0.05$).

The sensory profile was determined for BM potato chips using QDA, and an analysis of variance was carried out. Significant differences in color and oily descriptors were found, and the results of this study demonstrated that BM potato chips have a satisfactory acceptability, with color being the only descriptor that causes a certain rejection due to the presence of reddish blue shades.

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