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Research Article

Sensory Evaluation of Yam Nuggets (*Dioscorea alata L.*) of the Bottle Peak Genotype Obtained by Osmotic Dehydration

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Abstract: The objective of this study was to implement the osmodehydration process as a pre-treatment prior to the frying process for the preparation of yam nuggets, where the moisture, ash, fiber, protein, fat and carbohydrate content was evaluated according to A.O.A.C. (1990). The obtained nuggets were sensorially characterized with 11 trained testers using a 9 cm unstructured scale. Five treatments were evaluated by varying the amount of sodium chloride and sucrose (T1: 0, 0, T2: 2; 15, T3: 4; 30, T4: 6; 45, T5: 8; T1: 10, T2: 20, T3: 30, T4: 40, T5: 50) min and temperature (T1: 30, T2: 40, T3: 50, T4: 60, T5: 70) °C. Following the osmodehydration, the nuggets were subjected to immersion frying (180°C for 4 min). The data obtained was evaluated by means of an analysis of variance, Tukey's mean comparison test ($p \leq 0.05$). The physicochemical analysis showed statistically significant differences ($p \leq 0.05$) between the treatments, observing the influence of osmodehydration, where the increase in the values in the conditions of the process was reflected in the increase in the carbohydrate, fiber and ashes and decreased in moisture, fat and protein. For the Quantitative Descriptive Analysis, the tasters identified statistically significant differences ($p \leq 0.05$) for the attributes of color, odor, yam flavor, hardness, chewability, fracturability and sweet taste residual, with T5 presenting the characteristics with better scores, concluding that the application of osmodehydration improved the organoleptic characteristics of the nuggets.

Keywords: Contact time, frying immersion, osmodehidrating solution, sensory descriptive test, sensory profile, temperature at contact

INTRODUCTION

Yam is an excellent source of carbohydrates (25.3%), mineral salts such as calcium, iron and phosphorus (Dilworth *et al*., 2007), contains certain levels of vitamins A and C (Leonel *et al*., 2006). As well as B1 (thiamine), important in the growth of children and B5 of importance to the immune system (Pamplona, 2006). It also contains niacin (0.3 mg/100 g), riboflavin (0.03 mg/100 g) and thiamine (0.14 mg/100 g) (ICBF, 2015). In addition, their tubers possess most of the essential amino acids such as arginine, leucine, isoleucine and valine, with a less extent being histidine, tryptophan and methionine. It is noteworthy, it has low levels of fat and it is a good appetite stimulant and an excellent blood purifier (González Vega, 2012).

Small and medium-sized farmers of indigenous people grow yam in tropical America since pre-Columbian times (González Vega, 2012). In Colombia, it is harvested with low technological level, generally associated with cassava and corn crops (Corpoica, 2003). The harvesting of yams, in terms of agribusiness, is an activity that generates employment, whose annual numbers in the world reach significant values. Some authors point out that the tropical African countries of the western region, especially Nigeria, Côte D'ivoire and Ghana are the largest producers of yam worldwide (Baco *et al*., 2007).

Osmotic treatment is a dehydration technique generally used on fruits and vegetables; this treatment generates a reduction in the water activity of the food and, therefore, allows its storage for longer periods of time, at the same time it improves the stability and quality of the product (Castro-Giraldez *et al*., 2011). Osmotic dehydration is a conservation technology that reduces the postharvest losses of the fruit and provides an option to transform it, this conservation method is considered as a great alternative because of its low cost since it is a non-thermal process (Torres and Tabarquino, 2007). With frying, food acquires certain characteristics of color, texture and scent that is a consequence of the Maillard reaction and the absorption of volatile compounds present in it (Rossell, 1998; Bouchon and Aguilera, 2001; Achir *et al*., 2008).

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Carneiro *et al*. (2005) defines the Quantitative Descriptive Analysis (QDA) as a practice that allows a description of the sensory characteristics with precision in mathematical terms, through the identification, description and quantification of the sensory attributes of a product, that is, it describes the sensorial properties and measures the Intensity in which the tasters perceive them.

The obtention of yam nuggets from the Bottle Peak genotype pursues to add value to the yam, benefiting the producers since the demand for the raw material would be maximized, thus reducing postharvest losses, generating greater economic resources and an increase in the employment rate. It is an alternative to industrial use since it would produce a food of optimum quality, with adequate physicochemical characteristics and with good acceptability among the consumers of the product. Therefore, the main objective of this investigation was to physicochemically and sensorially characterize nuggets made from yam of the Bottle Peak genotype, using the osmotic dehydration process as pretreatment in the frying process by immersion.

MATERIALS AND METHODS

Obtaining the raw material: The raw material used was the species *Dioscorea alata*, of the Bottle Peak genotype from the town of Ciénaga de Oro, Córdoba; it was selected by taking to account the physical characteristics, the healthiness of the product and the same crop batch. The raw materials (sugar, salt, palm oil) were purchased in the local commerce of the city of Montería.

The obtained raw material was free of impurities, bruises, insects, etc., then it was washed with drinking water and sanitized by immersion in a 0.5% sodium hypochlorite solution for 15 min, then it was rinsed with ozonized water and left to dry for a period of six hours at room temperature, then stored at refrigeration temperature until processing (Vergara Gallego, 2015).

Physicochemical characterization of the raw material: The evaluation of the physicochemical composition of the yam (*Dioscorea alata*) of the Bottle Peak genotype, was developed according to the AOAC (1990) methodology; in order to determine the amount of nutrients that could be influenced by the nugget processing, among them: Humidity (A.O.A.C. 925,10); Ethereal extract or fat (A.O.A.C. 920.85); Crude protein (A.O.A.C. 920, 87); Ash (A.O.A.C. 923.03); Crude fiber (A.O.A.C. 920, 86).

The total percentage of carbohydrates was calculated by difference, adding up the previous analyzes and subtracting that value to 100.

Obtaining the yam nuggets of the bottle peak genotype: Two cm edge cubes were obtained which were subjected to osmotic dehydration and stored in polyethylene sealed bags, 2.5 µm gauges, labeled and frozen at -20°C.

Table 1: Osmotic dehydration parameters

	Treatments				
Variables	T_1	T_2	T_3	T_4	T_5
Time (min)	10	20	30	40	50
Temperature (°C)	30	40	50	60	70
NaCl (g/100 mL)	0	2	4	6	8
Sucrose (g/100 mL)	0	15	30	45	60

The osmotic dehydration process was performed following the methodology proposed by Diniz *et al*. (2006). The osmotic dehydration parameters are shown in Table 1.

After the contact time of the nuggets with the osmotic solution at the temperature specified for each treatment, the excess water was removed by drainage, then the nuggets were transferred to a tray to dry the surface with absorbent towel paper. Finally, the nuggets were weighed after osmodehydration.

The frying by immersion process was carried out in industrial fryers with a capacity of 5 L as proposed by De Paula (2009), using palm oil at 180°C for 4 min.

Quantitative descriptive analysis: The Quantitative Descriptive Analysis was developed by 11 trained tasters, who established descriptive terminology, unified attributes during the consensus step and characterized using a 9 cm unstructured scale, where 0 cm is weak and 9 cm is strong. The tasters received three samples for each session until all five treatments were completed.

The evaluation was done in triplicate. The samples were presented in different order for each session in order to avoid vices. Samples of yam nuggets were presented to the tasters served in covered disposable plates to facilitate the perception of the smell and subsequent aroma. Random numbers of three digits were assigned to the samples and chopsticks to taste accompanied the samples as well. A glass of water at room temperature was used to remove grease residues.

Experimental design and statistical evaluation: The results of the Quantitative Descriptive Analysis were analyzed by a completely randomized design (QDA) with three replicates per treatment and were submitted to ANOVA and Tukey's test ($p \le 0.05$); having as sources of variation the samples and their repetitions ($p \le 0.05$). All data were analyzed using the program, SAS, Statistical Analysis Systems (version 8.1; SAS Institute, Inc. Cary, NC.).

RESULTS AND DISCUSSION

Physicochemical characterization: The established conditions for obtaining the yam nuggets with osmotic dehydration and the frying process generated statistically significant differences ($p \le 0.05$) in the physicochemical characterization of these nuggets (Table 2).

Table 2: Physicochemical composition of yam nuggets after the frying process *

Tment.	Humidity (%)	Ashes (%)	Fat (%)	Protein (%)	Fiber (%)	CHO (%)
T1	56.65±1.35a	1.50±0.01e	12.23±0.02a	5.05±0.07a	2.45±0.06b	22.13±1.24d
T2	50.16±1.41b	1.83±0.01d	5.90±0.01b	4.44±0.08b	3.26±0.08a	34.41±1.43c
T3	47.60±0.67bc	2.13±0.03c	5.57±0.01bc	4.41±0.10b	3.29±0.23a	37.01±0.58b
T4	46.11±0.53cd	2.27±0.06b	5.42±0.28cd	4.03±0.06c	3.46±0.23a	38.72±0.60ab
T5	44.83±0.43d	2.46±0.03a	5.19±0.01d	3.84±0.06c	3.65±0.32a	40.03±0.19a

*: Average of three replicates±standard deviation; **: Different letters in the same column denote significant statistical differences ($p \leq 0.05$)

Regarding the humidity percentage, a general decrease is observed in relation to the raw material used (74.42%); the treatments T1, T2, T3, T4 and T5 presented a humidity reduction of 23.88, 32.60, 36.04, 38.04 and 39.76% respectively, thus indicating that the increase in the conditions of osmotic dehydration values, generated a greater loss of water in the nuggets. In the osmodehydration, the product gains solutes in the intracellular spaces that were occupied by the water and later in the frying process, the water that was not released in the pretreatment is removed by evaporation (Rodríguez De la Pava *et al*., 2013).

Tortoe (2010) states that an increase in the concentration of the osmotic solution leads to a higher rate of water loss until reaching an equilibrium level. In relation to the immersion time, an increase in this leads to a greater moisture loss during the osmotic dehydration (Ispir and Toğrul, 2009; Mundada *et al*., 2011). As for temperature, this is the most important factor affecting the osmotic transfer rate (Tortoe, 2010), the increase in the temperature of the process accelerates the loss of water, while the absorption of solids is less affected (Tortoe, 2010; Khan, 2012).

As for the ash content, the analysis of variance showed that this variable presents statistically significant differences ($p \leq 0.05$) between the treatments. Yet, contrary to is observed that all treatments differ statistically from each other and that there was an increase in ash content in relation to the raw material (1.40%), similarly De Paula *et al*. (2016) observed that the yam nuggets osmodehydration of the Bottle Peak genotype presented a significant increase in this parameter in relation to the raw material. Contrary to what happened with the nuggets of the Osito and Diamante genotypes.

From Table 1 it is observed that as the sodium chloride content in the osmotic solution increased, the ash content increased, which is why the T5 treatment is the one with the highest content of this parameter. Likewise, Vergara Gallego (2015) affirmed that the behavior of the ash content in the nuggets of the osmotically dehydrated genotypes relative to the control is proportional to the reduction of water and as a consequence of the absorption of sodium chloride contained in the osmotic solution. Regarding the fat percentage in the different treatments, it presented significant statistical differences ($p \leq 0.05$). In regard to the raw material, there was a considerable increase in all the treatments due to the frying process, since the high temperature of the process caused the evaporation of the water, transferring it from the food to the surrounding oil and therefore gave an oil gain per part of the product. The treatment that presented greater oil absorption was the treatment T1 since the immersion solution of this did not contain any osmotic agent and there was an exchange of water and oil during the frying process. As for the behavior of this parameter among treatments the T5 treatment has a lower fat content, this means that there was less oil absorption on this treatment even when the humidity is low, but the carbohydrate content is high, that is, the intracellular spaces were occupied by the osmotic agents and not entirely by the oil derived from the frying process. These results are similar to those obtained by Vergara Gallego (2015), where the fried yam nuggets of the three genotypes presented higher fat content in relation to the raw material, showing a smaller quantity of this parameter when compared to control, which was not subjected to any osmotic agents. Of the three genotypes only Diamante did not present statistically significant differences ($p \leq 0.05$).

The analysis of variance of the protein content showed that in this parameter there are statistically significant differences ($p \leq 0.05$) between the treatments. In relation to the raw material (5.29%) a decrease in the amount of protein was observed. Concerning the behavior of this parameter between the treatments, it is observed that T1 is the one with the highest amount of protein and the one that differs statistically from the other treatments. T2 and T3 are significantly the same ($p \leq 0.05$) even though it is the T2 treatment that has the highest protein content of this pair of means, a similar case occurs with treatment T4 and T5 being the last the one that has the lower content of this variable. The reduction in protein content in fried yam nuggets osmodehydration is due to the fact that during the osmodehydration process, the salts enter through the cell membrane altering the colloidal properties of the proteins and the water-protein ratio (Fennema, 1993).

Regarding the fiber content, the statistical analysis shows that there are highly significant differences ($p \leq 0.05$). Treatment T1 is the one that differs statistically from the other treatments, which was not submitted to contact with the osmotic agents; in relation to the raw material, this treatment did not present a considerable increase. The treatments T2, T3, T4 and T5 presented an increase in the amount of fiber, although there were no significant statistical differences between them. De Paula *et al*. (2016), where a similar behavior was also observed for yam nuggets obtained from the Bottle Peak and Diamond genotypes, where the fiber content increased in relation to the control,

Table 3: Quantitative descriptive analysis performed on the nuggets of yams osmodehydration and fried submitted to the different treatments*

	Treatments				
Attributes	T1	T2	T3	T4	T5
Yam odor	4.90a	3.47ab	3.59ab	3.62a	2.76b
Color	1.49e	2.76d	4.20c	6.86b	8.19a
Remaining oil	4.25a	4.12a	4.76a	3.69a	3.19a
Yam aroma	5.56a	3.97ab	4.14ab	3.68b	3.00b
Yam flavor	5.67a	3.52ab	3.96ab	4.12ab	2.73b
Crocancy	2.70a	3.12a	3.74a	4.19a	4.21a
Crunchiness	2.73a	2.94a	3.23a	4.62a	4.88a
Hardness	4.52ab	4.58a	4.74a	2.76b	3.31ab
Chewability	4.70a	3.53ab	3.68ab	2.83b	2.58b
Fracturability	4.64a	3.38ab	3.73ab	3.28ab	2.54b
Adhesiveness	3.06a	3.85a	3.71a	2.94a	2.53a
Residual sweet taste	1.12c	3.41b	4.95ab	4.71ab	6.04a

*: Different letters in the same row denote significant statistical differences ($p \leq 0.05$)

otherwise occurred in the Osito genotype, reported similar values. Tadesse *et al*. (2015) attributed the variations in fiber content to the concentrations of the brine prior to drying the carrot slices.

There were statistically significant differences in the carbohydrate content ($p \leq 0.05$) between the treatments. Taking into account the carbohydrate percentage in the raw material, it was observed that there was an increase in this parameter in the treatments where the osmotic dehydration was performed. Treatments differ from each other except for T3 and T4 were no statistically significant differences were observed, with T4 treatment having the highest carbohydrate content between these two, generally and the T5 treatment contains the highest amount of carbohydrates. It is observed that the increase in the concentration of sucrose in the osmotic solution produced an increase in the carbohydrate content. Values and similar behavior reported by De Paula *et al*. (2016) and Rodríguez De la Pava *et al*. (2013) where it was analyzed that the considerable increase of carbohydrates is due to both the reduction of mass and the absorption during the procedure, in addition, the concentration of the solutes is due to the evaporation of water during the frying process.

Quantitative descriptive analysis: In the Quantitative Descriptive Analysis (QDA) the tasters established statistically significant differences ($p \leq 0.05$) among the treatments for the attributes of yam; color, yam aroma, yam flavor, hardness, chewability, fracturability and residual sweet taste. For the attributes of residual oil, crocancy, crunchiness and adhesiveness the tasters did not reveal significant statistical differences between the samples (Table 3).

As for the yam smell attribute, the tasters managed to perceive certain differences, being the highest value of treatment T1 which was not subjected to the osmodehydrating agents and standing out the T5 treatment for throwing the lowest value, which was submitted to the highest values of concentration of the solution, time and temperature of immersion. It can be observed that as the values of the studied variables increased, the score for the odor attribute decreased. Vergara Gallego (2015) reports that osmodehydration treatment slightly diminishes the odor of yams from the nuggets of the three genotypes studied.

The tasters perceived the color differences that appeared in the different treatments, registering the highest value of the T5 treatment which has the darker color and the T1 treatment the lighter color which had the lowest mean. As the conditions of the variables in the treatments increased, the values given by the tasters increased. According to Oyelade *et al*. (2008) on the surface of the fried osmodehydrated products, a crust or wrapping is formed since it visually forms a hard surface, presenting a golden yellow color due to the degradation of proteins and sugars by the action of heat and browning non-enzymatic and caramelization (Maillard reaction). Vergara Gallego (2015) who attributed the color change in the yam nuggets to the osmotic dehydration and, of the genotypes studied, only Bottle Peak, obtained similar results and Osito presented statistically significant differences in relation to the control. In the processes of dehydration, there are changes and losses of color, since the characteristics of the surface of the food and therefore its color and reflectance, are changed. Also, enzymatic browning, which originates from polyphenol oxidase, causes a rapidly darkening mainly on the outside of the samples (Rahman and Perera, 1999; Lee and Schwartz, 2006).

The testers did not distinguish differences in the residual oil attribute, attributed the lowest value of the T5 treatment, which was the one that reported the lowest fat percentage for the physicochemical characterization.

In the aroma and yam flavor, the testers found significant differences between treatments T1 and T5. With the mean value being higher for the T1 treatment and the lower value given for the T5 treatment that has the highest carbohydrate content derived from osmodehydration and thus the one that underwent greater changes in the volatile compounds from being exposed to a higher temperature for a greater time. Rossell (1998) explains that with the fried foods acquire certain characteristics of color, texture and aroma that are a consequence of the Maillard reaction and the absorption of the food of volatile compounds present in it.

Regarding the attributes of crocancy and crunchiness, the tasters did not perceive significant differences, attributing the highest score to the T5 treatment and the lowest score to the T1 treatment in both sensory attributes, the crocancy related to the fragility and therefore to less humid products gave, as a result, the scores shown in Table 3. The crisp texture is due to protein coagulation, starch, gelatin and partial dehydration of the product (Morales Ravano, 2008), occurring mostly in T5, which was exposed, to the highest temperature which could denature the proteins and gelling starch and that was also the one that presented, in the physicochemical characterization, the lower percentage of humidity.

The hardness attribute presented significant differences between the T4 treatment when compared with the T2 and T3 treatments, observing the highest score for the T3 treatment and the lowest for the T4. Vergara-Gallego *et al*. (2016) did not find significant differences between the control treatment and osmodehydration treatment, but observed that osmotic dehydration decreases the hardness of the nuggets in both Diamante and Osito.

As for chewability, it was observed that the highest value was obtained by the T1 treatment, which has the highest humidity and weight gain (Table 2) and the lowest score was obtained by the T5 treatment that showed lower humidity in the physicochemical characterization (Table 2) and greater weight loss.

The fracturability shows that the treatments T1 and T5 differ from each other, the latter having the highest value of the mean, in contrast to the T1 treatment with the highest score. This attribute is associated with the hardness in which the food crumbles, creaks or bursts (Bourne, 1978; Szczesniak, 2002) and it can be shown that for the sensorially measured hardness T1 treatment has a higher rating than T5. Contrary to the results observed by Vergara-Gallego *et al*. (2016) that when applying osmodehydration the fracturability increased.

In relation to the adhesiveness, it is observed that there were no significant differences between the treatments. This attribute represents the work required to take the food from the palate (Londoño Ospina, 2009), which is why the T5 treatment was the one that scored lower because it requires less work due to its lower moisture content.

As for the sweet residual taste, the tasters perceived differences between the treatments, indicating that the T1 treatment has a lower sweet taste residual, which showed lower carbohydrate content in the physicochemical composition. The T5 treatment was noted for having the highest score and physicochemically has the highest carbohydrate content, as the treatment is subjected to the highest concentration of the osmodehydrating solution.

CONCLUSION

The pretreatment of osmodehydration prior to frying proved to be effective in the reduction of water in the product, reflected in weight loss and then in the physicochemical composition, where there was a decrease in moisture content.

For the behavior of the samples in the physicochemical analysis, it was evident that as the conditions of the osmotic dehydration process increased (concentration of the osmotic solution, time and immersion temperature) there was an increase in the total carbohydrate, ash and fiber and one decrease in percentage of fat, protein and moisture.

In the Quantitative Descriptive Analysis (QDA), the testers showed that by increasing the osmodehydration process conditions, desirable characteristics were obtained, giving higher values for color, crispness, crunchiness and sweet residual taste and lower scent, aroma, yam flavor, adhesiveness, fracturability, chewability, hardness and remaining oil.

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CONFLICT OF INTEREST

This manuscript was prepared and reviewed with the participation of all the authors, who declare that there is no conflict of interests that jeopardizes the validity of the presented results.

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