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Research Article

Sensorial and Physicochemical Characterization of a Restructured Fried Sweet Potato (*Ipomonea batata L.*) Using a Gelation System

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Abstract: The objective of this study was prepared a fried restructured sweet potato using an alginate/sulfate/Tripolyphosphate gelation System (PPTS) evaluating sensory and nutritional properties. Fried products, although very desirable, have a disadvantage in that their fat contents are high. The gelling system provides a product with consistent texture and acceptable by the consumer 15 formulations were prepared varying concentrations of alginate (0.35-0.70 g/100 g), calcium sulfate (0.50-0.75 g/100 g) and PPTS (0.09-0.18 g/100 g). The ingredients were mixed until the gel was obtained, then embedded in guts 2 cm in diameter and stored at -20°C. The fried products were characterized through the AOAC (2012) methods, the preference (ordering), sensorial acceptance (hedonic scale of 9 points) and intention to buy (5 points) were evaluated with 50 consumers. Data were analyzed by analysis of variance and Tukey's test ($p \leq 0.05$). The formulations presented differences ($p \leq 0.05$), those with the lowest fat absorption were F10 (25.72%) and F14 (26.38%), with F11 (27.51%) and F13 (27.78%). The ones with the highest water retention were formulations F12 (49.07%) and F9 (48.17%) ($p \leq 0.05$). The fiber and protein contents of the formulations showed no differences ($p > 0.05$). The most preferred formulations were F1, F6, F10, F11 and F14 ($p \leq 0.05$). The tasters did not find significant differences ($p > 0.05$), in the attributes of softness, crocancy and flavor to sweet potato. Formulations F6, F10 and F11 were among the terms of greater enjoyability and those with better intention to purchase were formulations F10 and F11 ($p \leq 0.05$).

Keywords: Attributes, fat absorption, preference, purchase intention, sensory acceptance, taster

INTRODUCTION

The world production of sweet potato was 106.601.602 tons by 2014, where the continents of Asia and Africa contributed 74.30 and 21.22% respectively of the total produced. For the same year, the continent of America recorded a production of 3,828,140 tons (FAOSTAT, 2017). Sweet potato occupies the sixth place in the most important foods, after rice, wheat, potatoes, corn and cassava (Shekhar *et al*., 2015); and is widely cultivated for its nutritional attributes and health benefits (Lee *et al*., 2012). Sweet potato has been cultivated traditionally, but its low industrial transformation has turned it into a little exploited raw material; looking for an exit to the previous one the tubers can be processed to nonperishable products, such as flour or starches, using conventional technological processes like the dehydration and milling (Pérez and Pacheco de Delahaye, 2005).

A product is called restructured when it is chopped and then a different structure is created with or without the addition of other ingredients, this process will give a new appearance and a new texture (Sánchez Alonso *et al*., 2004). In general, the preparation of restructured plant originates from knowledge of the raw material, followed by its disintegration, application of additives and condiments for subsequent molding and freezing, with or without pre-frying (De Paula, 2009).

Gelation is the property of the starch to form a gel and can be induced by heat or chemically applied, depending on the gelling agent: pectin, lecithin, carrageenan, alginate, agar, xanthan (Cubero *et al*., 2002). Among the polysaccharides, hydrocolloids are frequently used as thickeners, stabilizers and gelling agents in food processing. In fact, alginate has become an interesting option thanks to its ability to form irreversible ionotropic gels under specific conditions of low temperature and in the presence of bivalent ions such as calcium and phosphorus (Roopa, 2010). All these characteristics have contributed to the development of semi-soft or semi-moist products through different textures such as fruit by-products, vegetables, restructured fish and meat, desserts and custard, among others (Walewijk *et al*., 2008).

A fried restructured sweet potato with a system of glycation capable of absorbing the least amount of oil during frying with excellent sensorial characteristics was elaborated.

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MATERIALS AND METHODS

For the elaboration of the restructured product, we used the variety export provided by Corpoica Turipaná of the town of Cereté-Córdoba. Similarly, alginate, calcium sulfate dihydrate and Sodium Tripolyphosphate (PPTS) were supplied by the University of Córdoba.

Obtaining the sweet potato flour: The production of sweet potato flour was carried out following the methodology of Trancoso-Reyes *et al*. (2016) in which, after washing the potato, it was cut into 6 mm thick slices, dried at 60°C for 10 h in a forced air oven and temperature controlled. After dehydration, the slices were ground and passed through a 60 mesh sieve. The obtained flour was packed in hermetically sealed polyethylene bags and stored at 4°C until use.

Preparation of restructured sweet potatoes: Restructured sweet potato formulations were developed; with variations in the concentration of alginate, calcium sulfate dihydrate ($CaSO_4.2H_2O$) and Sodium Tripolyphosphate (PPTS), obtaining 15 formulations (Table 1) and a control, in which the concentrations of the ingredients used on the gelling system.

The puree was obtained after peeling the sweet potatoes, making slices of 6 mm, scalding at 80°C and subsequent grinding. The ingredients were mixed for 3 min in a JAVAR mixer with a capacity of 20 L at 40 rpm until the components were homogeneous. Three minutes for gel formation, immediately introduced into sausage casings of 2 cm in diameter, these were cut to form rolls of approximately 20 cm long-lashed at the ends. The rolls were stored for 24 h at -20°C and then cut manually into 2 cm pieces and stored until fried.

Evaluation of the restructured fried sweet potatoes: Moisture loss: Was calculated using the procedure of Standards AOAC 925.10 (2012).

Oil absorption: It was determined using a Soxhlet equipment, according to methodology 5.1.1.c (AOAC 920.85) (AOAC, 2012) in a moisture-free sample, in triplicate. Absorption of oil was expressed as dry basis percentage.

Physicochemical composition: The percentage of protein, ash, the crude fiber according to AOAC methodology (2012) was determined. The percentage of total carbohydrates was calculated by difference, adding up the previous analyzes and subtracting that value to 100.

Evaluation of the level of preference of the restructured protean: The degree of preference was determined between the samples, using a sorting test, in which the consumers were indicated to choose the sample of their preference (Ramirez Navas *et al*., 2014), using a panel of tasters made up of 50 potential consumers of the product orally. The samples were served in white plastic plates, coded with random numbers of three digits and presented simultaneously in a randomized order, the tasters ordered decreasingly, according to their preference (Ng *et al*., 2012).

Determination of acceptance of the selected restructured sweet potatoes: The acceptability of the samples of restructured selected sweet potatoes in the previous stage was evaluated with the participation of 50 potential consumers of the product recruited verbally. The samples were served on white plastic plates, coded with randomized numbers of three digits, presented simultaneously and in random order to the tasters. For this, a mixed nine-point hedonic scale and a five-point scale were used to determine the purchase intention. The evaluated attributes were the smoothness, crocancy, oiliness sensation and sweet potato flavor.

Experimental design and statistical evaluation: The results of the physicochemical and sensory analysis were analyzed by a Completely randomized Design (DCA)

Table 1: The concentration of ingredients (g/100 g) for different formulations of fried sweet potato restructured

	Real scale					
Formulations	Alginate	Calcium sulfate	PPTS	Saccharose	Flour	Puree
F1	0.35	0.50	0.09	4	8	87.06
F2	0.70	0.50	0.09	4	8	86.71
F3	0.35	0.75	0.09	4	8	86.81
F4	0.70	0.75	0.09	4	8	86.46
F5	0.35	0.50	0.18	4	8	86.97
F6	0.70	0.50	0.18	4	8	86.62
F7	0.35	0.75	0.18	4	8	86.72
F8	0.70	0.75	0.18	4	8	86.37
F9	0.23	0.63	0.14	4	8	87.00
F10	0.82	0.63	0.14	4	8	86.41
F11	0.53	0.41	0.14	4	8	86.92
F12	0.53	0.84	0.14	4	8	86.49
F13	0.53	0.63	0.06	4	8	86.78
F14	0.53	0.63	0.21	4	8	86.63
F15	0.53	0.63	0.14	4	8	86.70
Control	0.00	0.00	0.00	4	8	88.00

Table 2: The physicochemical composition of the fried restructured sweet potatoes with the gelling system* (%)

Formulation	Humidity	Ash	Fat absorption	Protein	Fiber	Carbohydrates
F1	39.94±2.38e	1.89±0.22ef	30.70±0.01f	3.64±0.09a	3.91±0.23a	19.90±2.34ab
F2	40.19±0.84de	1.75±0.09f	32.13±0.03bc	4.00±0.35a	4.55±0.65a	17.37±1.30abc
F3	46.74±0.89ab	1.87±0.17ef	35.11±0.29a	3.23±0.03a	4.42±0.31a	8.62±0.62e
F4	44.93±1.68abc	2.30±0.15ed	31.49±0.01cde	3.90±0.26a	4.40±0.23a	12.97±1.23cde
F5	41.23±2.29cde	1.77±0.11f	31.06±0.03def	4.19±0.88a	3.48±0.90a	18.36±3.07abc
F6	39.54±1.18e	2.75±0.02abcd	28.51±0.02g	4.04±0.02a	3.94±1.12a	21.21±1.54a
F7	41.48±2.92cde	2.69±0.08bcd	32.06±0.02cb	3.19±0.62a	4.13±1.31a	16.43±4.81abcd
F8	41.02±0.82cde	2.77±0.19abcd	27.31±0.02h	4.34±0.14a	4.35±0.41a	20.20±0.67ab
F9	48.17±0.33a	2.41±0.15cd	31.00±0.07ef	3.85±0.15a	3.23±0.19a	11.39±0.29de
F10	44.53±1.03abcd	2.62±0.16bcd	25.72±0.75i	3.94±0.17a	4.37±0.61a	18.47±0.21abc
F11	46.75±0.73ab	2.32±0.20ed	27.51±0.05h	3.96±0.48a	4.65±1.12a	14.79±1.23bcd
F12	49.07±1.60a	3.05±0.17ab	32.38±0.01b	3.78±0.47a	4.18±0.13a	7.59±1.94e
F13	45.22±0.68abc	2.69±0.30bcd	27.78±0.02h	3.39±0.65a	4.73±1.15a	16.16±0.52abcd
F14	43.29±0.20abcd	3.23±0.06a	26.38±0.36i	4.10±1.05a	4.48±0.55a	18.15±1.05abc
F15	40.33±1.79de	2.83±0.14abc	31.75±0.25bcd	4.11±1.34a	4.36±0.90a	16.61±0.90abcd

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

with three replicates per treatment and were submitted to ANOVA and Tukey's test ($p \leq 0.05$). All data were analyzed using the Statistical Analysis Systems program (SAS, 2009), evaluation version.

RESULTS AND DISCUSSION

Physicochemical characterization: The physicochemical composition of the different formulations of the restructured fried sweet potato with the gelation system calcium alginate-sulfate-PPTS are shown in Table 2, which showed statistically significant differences ($p \leq 0.05$), in moisture contents, ash, fat absorption and carbohydrates; however in the values of protein and fiber there were no statistically significant differences ($p > 0.05$).

On the moisture content of the formulations, there were statistically significant differences ($p \leq 0.05$), this indicates that the combination of alginate-phosphorus-calcium influenced the water retention, thanks to the formation of a gelling system in the restructured matrix (Avendaño-Romero *et al*., 2013). The formulation F12 (49.07±1.60%) and F9 (48.17±0.33%) were the most important ones, these presented statistically significant differences ($p \leq 0.05$) to the formulations F1 (39.943±2.38%) and F6 (39.54±1.18%) who had the lowest moisture value after frying. However, the formulations F3, F4, F10, F11, F13 and F14 are equal to each other and exhibit intermediate moisture contents, but differ statistically ($p \leq 0.05$) to the formulations F1 and F6. These results differ from those of De Greissing (2014) for a restructured chicken, reporting moisture contents of 63.03% and those of Contreras and Melina (2014) that obtained values of 65.55% for a restructured alpaca with pecan.

Regarding ash content, the formulations presented statistically significant differences ($p \leq 0.05$), which is due to the variation of calcium and phosphorus in the gelling system (Table 2). Formulations F12 (3.05±0.17%) and F14 (3.23±0.06%) did not differ statistically ($p > 0.05$) and had the highest ash content. These contents are similar to those reported by Agulló and Asunción (2007) who elaborated a meat restructuring with the incorporation of walnut (3.51%) and those of Cárcamo and Dickson (2016) who elaborated a restructured with legumes (2,50 to 3,51%). Although the formulations F1, F2, F3 and F5 were statistically the same ($p > 0.05$), they exhibited the lowest ash contents with 1.89±0.22%, 1.75±0.09%, 1.867±0.17% and 1.77±0.11% respectively; but in turn are statistically different ($p \leq 0.05$) to formulations F12 and F14, which presented the highest values. The values of these formulations are similar to those found by Contreras and Melina (2014) (1.48%). Formulas F4, F6, F7, F8, F9, F10, F11, F13 and F15 which are statistically the same ($p > 0.05$) showed intermediate values of ash with a range of 2.30±0.15% at 2.83±0.14%.

F1, F6, F8, F10 and F14 do not differ from each other ($p > 0.05$) but are statistically different ($p \leq 0.05$) from F3 and F12. The formulations in question had the highest carbohydrate content of 19.90±2.34%, 21.21±1.54%, 20.20±0.67%, 18.47±0.21% and 18.15±1.05%, respectively and coincide among the formulations of lower fat absorption.

In regards to the fat absorption of the restructured sweet potatoes, the formulations showed significant differences ($p \leq 0.05$), with the lowest content being the formulations F10 (25.72±0.75%) and F14 (26.38±0.36%), which are statistically equal ($p > 0.05$). In contrast, the one with the highest fat absorption was the F3 formulation with 35.11±0.29%, with significant differences ($p \leq 0.05$) in relation to the others. The formulations F4, F5 and F9 presented intermediate fat absorption (31.49±0.01, 31.06±0.03 and 31.00±0.07 respectively) and were statistically the same ($p \geq 0.05$). These differences in the fat absorption of the formulations are due to the variation of the alginate-phosphorus-calcium concentrations, which, when

forming the gel, trap the water in the matrix and prevent the fat from entering the food (De Paula, 2009; Hattrem *et al*., 2014; Nilsen-Nygaard *et al*., 2016). These contents are associated with the exchange between water and fat in the restructured ones, reason why the content of humidity varies with respect to the absorption of oil during the frying (Table 2).

When comparing the restructured sweet potatoes with other products, for example, potato chips, fat absorption ranges from 35 to 40% (Thanatuksorn *et al*., 2010), for green banana slices is 37.7% (Lucas *et al*., 2012) which demonstrates the efficiency of the gelation system of calcium alginate-sulphate-PTS in the reduction of fat absorption in the restructured sweet potatoes, since the contents were below those mentioned above (De Paula, 2009; Porta *et al*., 2012).

For the protein and fiber contents of the restructured sweet potatoes, there were no statistically significant differences ($p>0.05$); which is due to the fact that the ingredients that provide protein and fiber are flour and puree, the former was fixed and the latter presented few variations in the formulations (Table 1). The F5, F8, F14 and F15 formulations with 4.19±0.88%, 4.34±0.14%, 4.10±1.05% and 4.11±1.34% were highlighted with the F2, F3, F4, F10, F11, F13 and F14 formulations with 4.55±0.65%, 4.42±0.31% and 4.40±0.23%, 4.37±0.61%, 4.65±1.12%, 4.73±1.15% and 4.48±0.55% respectively. Fiber is important in the diet because it helps to improve the functioning of the digestive system, lower blood cholesterol level and has a favorable influence on the glycemic index, prevention of colon cancer and decreases constipation (Slavin, 2005; Tecson-Mendoza, 2007).

Regarding carbohydrates, there were statistically significant differences ($p\leq0.05$); indicating that the variations of calcium sulfate-sulfate-PPTS influenced water retention, fat absorption, ash and hence the carbohydrate content of the formulations (Table 2). Formulations F3 and F12 were the lowest carbohydrate, with 8.62±0.62% and 7.59±1.94% respectively and differed statistically ($p\leq0.05$) from the other formulations. Formulations F1, F6, F8, F10 and F14 do not differ from each other ($p>0.05$) but are statistically different ($p\leq0.05$) from F3 and F12; the formulations in question had the highest carbohydrate content of 19.90±2.34%, 21.21±1.54%, 20.20±0.67%, 18.47±0.21% and 18.15±1.05% respectively and coincide among the formulations of lower fat absorption.

For the control formulation, none of the variables could be quantified, because with the flour and the sweet potato, the gel was not generated enough to keep the rest of the ingredients together during the frying, in which case it happened according to De Paula (2009) in the restructured malanga, where the control formulation could be fried without fracture and the variables of moisture and fat absorption after frying was quantified.

Table 3: Results of the sorting-preference test by the Friedman test

Block 1				
F5	F15	F4	F8	F11
163a	160a	158a	157a	112b
Block 2				
F2	F7	F13	F1	F10
183a	172a	161a	117b	115b
Block 3				
F3	F12	F9	F14	F6
184a	180a	159a	113a	110a

*: Measures with the same letter do not differ from each other at the 5% level for the Friedman test (DMS = 44)

Evaluation of the preference for ordering the restructured fried potatoes with a gelling system: For the order-preference test, 50 evaluations were carried out in which the consumer tasters ordered the formulations giving the mark 1 for the most preferred and 5 for the less preferred. The samples were served in batches of 5 formulations, arranged completely at random. The sums of the orders, considered as the results obtained from the test of Friedman are presented in Table 3.

According to the sum of orders test, the Significant Minimum Difference (DMS) value to obtain a significant difference between the formulations at the 5% level is 44. In this sense, it is identified that for Lot 1, the most preferred formulation was F11; for Lot 2 the formulations F1 and F10 and Lot 3, the formulations F14 and F6; these being the most preferred and statistically different within their groups ($p\leq0.05$).

For sensory acceptance and purchase intent formulations of fried restructured sweet potato with a gelling system, F1, F6, F10, F11 and F14 formulations were selected, which were the most preferred (Table 3) and exhibited better characteristics of fat absorption, water retention and other physicochemical properties (Table 2).

Evaluation of the level of acceptance and purchase intention the restructured fried sweet potato with the gelling system: The acceptance by attribute and purchase intention of the formulations of the restructured fried sweet potato with the gelation system alginate-calcium sulfate-PPTS are shown in Table 4, statistically significant differences were showed ($p\leq0.05$) in the attribute of oily sensation and intention of purchase; however, the attributes of sweetness, crispness and sweet taste did not present statistically significant differences ($p>0.05$).

The softness of the formulations did not present statistically significant differences ($p>0.05$); all were located between the hedonic terms "I like slightly" to "I like moderately". Formulations F1 and F6 exhibited the lowest scores, which is related to the lower moisture contents (Table 1); however the formulations F10 and F11 showed the highest values, which coincides with higher moisture contents (Table 2).

Table 4: Acceptance by attributes and intention of purchase of the restructured fried sweet potatoes

Formulation	Softness	Crocancy	Oily sensation	Sweet potato flavor	Purchase intention
F1	6.40a	5.54a	5.76b	7.28a	2.94c
F6	6.36a	6.40a	6.64a	7.36a	3.24c
F10	6.68a	5.78a	7.22a	7.54a	4.26a
F11	6.82a	5.92a	6.74a	7.34a	4.08ab
F14	6.46a	6.32a	6.50ab	7.42a	3.46bc

Different letters in the same column denote statistically significant differences ($p \leq 0.05$)

For the attribute of crocancy the restructured sweet potatoes did not show statistically significant differences ($p>0.05$). The formulations F1, F10 and F11 were located in the hedonic terms "I am indifferent" to "I slightly like"; while the formulations F6 and F14 among "I slightly like" to "I like moderately".

Regarding the oily sensation, the restructured sweet potatoes showed statistically significant differences ($p \leq 0.05$). The formulation F1 was placed in the terms "I am indifferent" and "I like slightly" and F14 between "I like slightly" and "I like moderately" being these equals between them ($p>0.05$), it should be noted that F1 differs from the other formulations ($p \leq 0.05$). The F10 formulation was highlighted among the hedonic terms "I like moderately" to "I like it a lot", being attributed to the fact that it was the one with the lowest fat absorption (Table 2).

As for the flavor too sweet potato attribute the fried formulations with a gelation system, no statistically significant differences ($p>0.05$) were exhibited, which could be attributed to the fact that in all formulations of puree ratios and sweet potato flour were similar and equal, respectively (Table 1). The formulations were located between the hedonic terms "I like moderately" to "I like it very much", in which the F10 formulation was highlighted with the highest score.

For the intention of purchase of the restructured fried sweet potatoes, there were statistically significant differences ($p \leq 0.05$); the formula F1 was the lowest value and the tasters placed it in "Probably would not buy it" and "I have doubts if I would buy it", in addition, is equal to the formulations F6 and F14 ($p>0.05$), the latter being between "I have doubts if I would buy it" to "I would probably buy it." The F10 and F11 formulations have the most important means of purchase, located between the terms "I would probably buy it" and "If I would buy it", they do not agree with each other ($p>0.05$), but they are different ($p \leq 0.05$) to the other formulations, except F11 with F14 ($p>0.05$). In this sense, the formulations F10 and F11 are identified as having the best attitude in the intention of purchase which is related to the ones with the least fat absorption, with a considerable acceptance as the attributes of oily sensation and smoothness.

CONCLUSION

The use of the alginate-phosphorus-calcium gelation system was efficient in the elaboration of fried restructured sweet potatoes resulting in products with higher water retention and lower fat absorption. The highest water retention values were F12 (49.07%) and F9 (48.17%); however, the lowest fat absorption was obtained by formulations F10 (25.72%) and F14 (26.38%). Formulations F1, F6, F10, F11 and F14 were the most preferred. In the acceptance test, the tasters did not find significant differences ($p>0.05$) in the attributes of softness, crocancy and sweet taste, but for the oily sensation attribute, the tasters had significant differences ($p<0.05$) the least accepted formulation being F1 equal to F14. The intention of purchase of the tasters indicated that there is a significant difference between the formulations ($p \leq 0.05$), the formulations F10 and F11 being the ones that are standing out, ranging from "I would probably buy it" to "I would buy it". Formulation 10 was selected as the restructured sample that was the most pleasant and had the best physicochemical characteristics.

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CONFLICT OF INTEREST

The 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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