International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 26, No. 3, p. 63-71, 2025

INNSPUB

RESEARCH PAPER OPEN ACCESS

Effect of cassava starch-based edible gel on sensory and color properties of coated yam chips

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Key words: Yam, Cassava starch gel, Coated yam chips, Sensory parameters, Colorimetric parameters

http://dx.doi.org/10.12692/ijb/26.3.63-71 Article published on March 06, 2025

Abstract

The production of yam chips can add value to yam varieties. Chips are thin products that absorb a lot of oil during frying. To reduce this absorption, treatments such as coatings are applied to the chips before frying. The aim of this study was to evaluate the organoleptic quality and color of yam chips after coating them with cassava starch gel and frying. To this end, chips of two yam varieties (Bètè-Bètè and Anader) coated with 2%, 3% and 4% cassava starch gel were produced. Organoleptic and colorimetric parameters were then determined. For colorimetric parameters (L*, a*, b* and ΔE), results generally showed significant differences between varieties. These parameters were positively affected by the addition of cassava starch gel. The results of the sensory analysis showed that the coated yam chips were appreciated by the panelists. In general, yam chips coated with 4% cassava starch gel, whatever the variety, were the best accepted and appreciated. However, a comparison of 4% gel-coated yam chips for both varieties showed a better appreciation for the Bètè-Bètè variety. Coating with cassava starch gel can be proposed as an alternative and effective method for adding value to yam tubers.

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Introduction

Yam is a tuberous plant of the *Dioscorea* genus of the Dioscoreaceae family with more than 600 species of pharmacological value (Adifon *et al.*, 2019). Tubers consist mainly of carbohydrates, which account for 90% of dry matter, the main component being starch. Global yam production has been estimated at around 88 million tons in 2022 (FAOSTAT, 2024).

In Côte d'Ivoire, yams rank first among non-cereal food crops, with production exceeding 7 million tons (Coulibaly *et al.*, 2022). The main yam species grown are *D. rotundata* and *D. alata*. However, production is dominated by varieties of the *D. alata* species, which includes two better-known varieties (Bètè-Bètè and Florido) (Doumbia *et al.*, 2014). Tubers are consumed in various forms (foutou, boiled, braised, fried or raw) (Degras, 1986; Hamon *et al.,* 1997). However, not all aspects of yam tuber valorization in Côte d'Ivoire have been studied to date. Thus, with a view to adding value to yam tubers, the production of yam chips could present an interesting niche in this market (Attaie *et al.*, 1998).

Chips are thin-fried products obtained by several techniques (Liu *et al.,* 2021). Among these techniques, modification of size and thickness (Gamble *et al.*, 1987), pre-drying (Pedreschi and Moyano, 2005), modification of frying techniques (Mehta and Swinburn, 2001), frying medium (Berry *et al.,* 1999), cooking temperature (Mellema, 2003) and chip coating (Williams and Mittal, 1999) have been used to reduce the oil content in fried products.

Edible coating, a thin layer of edible material on the surface of the food product creates a semi-permeable barrier to gases, water vapor and volatile compounds (Rezagholizade-shirvan *et al.*, 2023). Surface coating of fried products can be considered a value-added process due to its effects on fried product quality, such as controlling moisture loss and oil absorption during frying, as well as providing nutrients, a crispy texture and the development of desired color (Dogan *et al.*, 2005). In addition, the coating formulation leads to an increase in the barrier property of the fried slices and prevents the creation of pores and cracks in the fried product (Su *et al.,* 2021). However, it is important to know the sensory perception of the resulting food (Varella and Fiszman, 2011). For this reason, Alimi *et al.* (2014) in their study evaluated consumer appreciation and sensory profile of egg and hydrocolloid coated fried yam chips. They concluded that acceptance of coated potato chips depended mainly on the concentration of hydrocolloids. Panelists preferred potato chips with minimal hydrocolloid treatment. Also, the study established that visual appearance, flavor and puffiness exerted a strong influence on the overall acceptability of coated potato chips. In this study, the coating of cassava starch-based edible chips at different concentrations was evaluated. The aim was to study the effect of cassava starch-based edible gel on the sensory and color properties of coated yam chips.

Materials and methods

Plant material

The plant material consisted of a variety of yam of the species *Dioscorea alata*, commonly known as Bètè Bètè, and a variety of yam of the species *Dioscorea caynensis rotundata*, commonly known as Anader, purchased on the local market in Abobo, Côte d'Ivoire. The cassava (*Manihot esculenta* Crantz) whose native starch extracts were used to make the coating gels were cassava roots of precisely the Olékanga variety taken from a FIRCA experimental field at Kangrassou- Aluibo in Côte d'Ivoire.

Cassava starch extraction

Starch was extracted using the method of Amani *et al.* (2004). The roots were peeled and cut into cylinders about 10 cm long using a stainless-steel knife, then washed twice with tap water. The pieces were then ground using an electric grinder (Silver crest, SC-1586, USA). The resulting grind was mixed in equal proportions with water and macerated with a spatula. The mixture was filtered through a series of sieves with mesh diameters of 500, 250 and 100 µm respectively, to obtain the starch milk. The resulting milk was alternately decanted and washed (at least 4 times). The resulting product was spread out on aluminum foil-covered trays and oven-dried at 48°C for 48 hours. The dry product was ground using an electric grinder (Silver crest, SC-1586, USA) and weighed. Native starches were stored at room temperature with a relative humidity of 85 ± 2%.

Starch gel preparation

To produce aqueous starch suspensions, starch powders were mixed with water at different rates (2%, 3% and 4%). 30% glycerol was added to the mixture. The mixture gradually heated from 30 °C to 95°C for 1 h on a hot plate to gel (Adjouman *et al*., 2017).

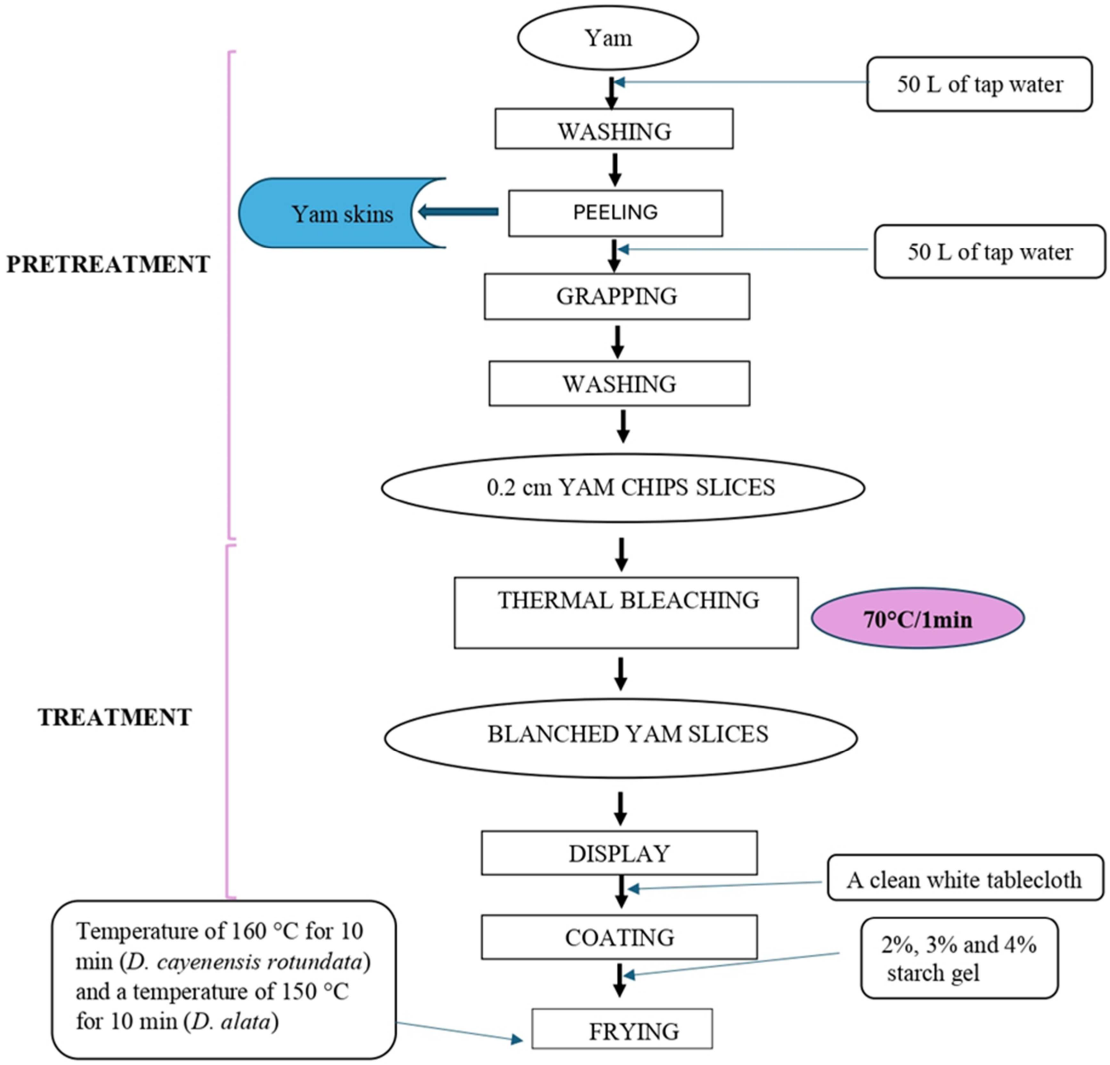

Fig. 1. Yam chips production flow chart

Preparation of coated chips

The coated yam chips were prepared according to the steps presented in the manufacturing diagram developed for this study (Fig. 1). Yam tubers were carefully washed in tap water (50 L) to remove debris and sand. After cleaning, the tubers were manually peeled using a stainless-steel knife and cut into strips using a chip cutter. The slices were rinsed immediately after cutting, drained and blotted dry in clean towels. The yam slices were blanched in water at 70°C for 1 minute. The temperature was measured with a thermometer (Digital Thermometer, TB300, China). They were then drained and blotted dry in clean towels.

The blanched slices were immersed in starch gel for 30 seconds. They were drained, then fried in refined palm oil (Dinor®, Unilever, Abidjan, Côte d'Ivoire). Frying was carried out in an electric fryer (NASCO, DF7703-GS, Ghana) equipped with a thermostat and a basket of metallized mesh. 730 grams of tuber slices (chips) were immersed and fried in 6 liters of hot oil. Frying time/temperature ratios were 10 min/150°C and 10 min/150°C respectively for Bètè-Bètè and Anader chips.

Color of yam chips

Chip color was assessed using a Konica Minolta chromameter (Chromameter CR-10 plus, Japan). Chip color was measured on both sides of the chips. The mean value of the L*, a*, b* values was measured and the chroma value (ΔE) was calculated using the formula below (Andres *et al.*, 2004).

$$(\Delta E) = \sqrt{(L*)2 + (a*)2 + (b*)2}$$

L*: from black to white;

a*: color changes from green (negative values) to red (positive values);

b*: color change from blue (negative values) to yellow (positive values)

Sensory analysis

Hedonic evaluation tests were carried out by naive tasters (N= 30), made up of students from NANGUI ABROGOUA University. Each dish was assessed globally, then specifically, on organoleptic characteristics such as appearance, smell, color and taste, crispness and general appreciation using a rating scale ranging from “extremely unpleasant”, “very unpleasant”, “unpleasant”, “less unpleasant”, “neither pleasant nor unpleasant”, “less pleasant”, “pleasant”, “very pleasant” to “extremely unpleasant”.

Statistical analysis of data

Physico-chemical analyses were carried out in trials of 3. Values are means ± standard deviation. The results of the analyses were subjected to an analysis of variance (ANOVA) at a significant level of 0.05 using STASTISTICA 7.1 software. Where samples differed significantly, Duncan's Test was used to determine which samples differed from each other.

Sensory analysis data in the form of scores were plotted against coated and uncoated potato chips and the parameters of interest.

Results

Evaluation of colorimetric parameters of yam chips of the Bètè-Bètè and Anader varieties

Table 1 shows the color parameters of yam chips uncoated and coated with different concentrations of cassava starch gel. The results show a significant difference ($p<0.05$). This difference was observed in the L* parameter of both varieties, the a* parameter of both varieties and the b* parameter of the Anader variety and the ΔE. However, no significant difference ($p>0.05$) was observed for parameter b*. For parameter L* a significant difference ($p<0.05$) was observed between the values obtained for cassava starch gel-coated chips (2%, 3% and 4%) and control yam chips (uncoated) for the Bètè-Bètè and Anader varieties. The highest values are 65.45±0.42 and 62.90±0.92. These values were obtained with uncoated yam chips (control) and with chips coated with 4% cassava starch gel for the Bètè-Bètè and Anader varieties respectively. Furthermore, the comparison between the two yam varieties shows a significant difference ($p<0.05$) between the different uncoated and coated yam chips of Bètè-Bètè and Anader. For parameter a*, the results show a significant difference ($p<0.05$) between coated and uncoated chips of the Bètè-Bètè and Anader varieties. The highest values are 7.40±0.18 and 10.18±0.02. These values were obtained with chips uncoated (control) and coated with 4% cassava starch gel for the Bètè-Bètè and Anader varieties respectively.

Furthermore, the comparison between varieties showed a significant difference ($p<0.05$) in a* parameter of chips coated with cassava gel (2%, 3% and 4%) and uncoated.

Concerning parameter b* the results show no significant difference ($p>0.05$) between uncoated and coated chips (2%, 3% and 4%) for the Bètè-Bètè variety. On the other hand, a significant difference ($p<0.05$) was observed for the Anader variety between uncoated and coated chips with 2%, 3% and 4% cassava starch gel. The largest values are -0.41±0.02 and 4.45±0.57. These values were obtained with chips coated at 2% for Bètè-Bètè and

3% for Anader. Comparison between yam varieties showed a significant difference (p<0.05) between coated and uncoated yam chips of different yam varieties. Results for the ΔE parameter showed a significant difference (p<0.05) for uncoated chips (control) and chips coated with 2%, 3% and 4% cassava gel respectively for the Bètè-Bètè and Anader varieties. The highest values are 27.16±0.47 and 26.05±0.80. These values were obtained with uncoated chips (control) and with chips coated with 4% cassava starch gel respectively for the Bètè-Bètè varieties. Finally, a significant difference (p<0.05) was observed after comparing results between uncoated chips (control) and chips coated with 3% and 4% cassava starch gel for yam varieties. On the other hand, for chips coated with 2% cassava starch gel, the results showed no significant difference (p>0.05) between varieties.

Table 1. Results of colorimetric parameters of yam chips

	L*		a*		b*		ΔE	
	Bètè-Bètè	Anader	Bètè-Bètè	Anader	Bètè-Bètè	Anader	Bètè-Bètè	Anader
T	65,45± 0,42^{c**}	42,11± 0,28^{b*}	7,40± 0,18^{c*}	7,35± 0,08^{b*}	-60± 0,36^{ab*}	2,78± 0,48^{a**}	27,16± 0,47^{c**}	16,56± 0,18^{a*}
FC=2 %	40,45± 1,58^{a*}	43,68± 0,56^{c**}	6,45± 0,34^{b*}	7,70± 0,05^{c**}	-,41± 0,02^{b*}	1,98± 0,02^{a**}	15,26± 0,96^{b*}	16,71± 0,45^{a*}
FC=3 %	3,46± 1,45^{ab**}	36,23± 0,50^{a*}	5,26± 0,05^{a*}	6,61± 0,14^{a**}	-,30± 0,80^{ab*}	4,45± 0,57^{b**}	17,51± 0,91^{a**}	14,23± 0,41^{b*}
FC=4 %	44,31± 3,02^{b*}	62,90± 0,92^{d**}	5,08± 0,32^{a*}	10,18± 0,02^{d**}	-2,50± 1,21^{a*}	2,71± 0,80^{a**}	18,46± 1,36^{a*}	26,05± 0,80^{c**}

Mean ± standard deviation. Values in the same column marked with alphabetical letters are significantly different at the 5% level according to Duncan's test of analysis of variance. Values in the same row marked with *, ** and *** are significantly different at the 5% level according to Duncan's test of analysis of variance. T: uncoated yam chips (control); FC=2%: 2% coated yam chips; FC=3%: 3% coated yam chips; FC=4%: 4% coated yam chips.

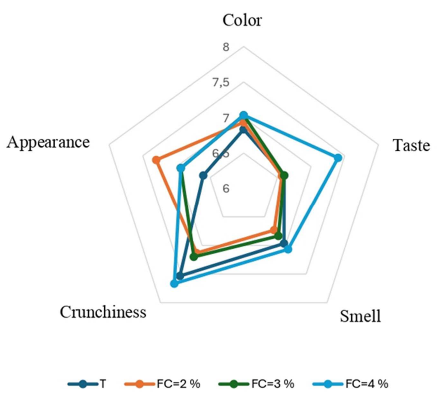

Fig. 2. Sensory profile of yam chips of the Bètè-Bètè variety (*D. alata*)

T: uncoated yam chips (control); FC=2%: 2% coated yam chips; FC=3%: 3% coated yam chips; FC=4%: 4% coated yam chips.

Organoleptic characteristics of yam chips

Bètè-Bètè variety yam chips

Fig. 2 shows the results of sensory testing of different formulations of yam chips of the Bètè-Bètè variety compared with the control (without cassava gel coating). The results show that there was no significant difference (p>0.05) between the studied parameters of color, taste, odor, crispness and appearance of the control chips (without cassava gel coating) and the chips coated with 2%, 3% and 4% cassava starch gel. Overall analysis of the sensory analysis data showed that panelists appreciated chips coated with 4% cassava starch gel. Fig. 3 shows fried chips of the Bètè-Bètè variety uncoated with control and coated with 2%, 3% and 4% cassava starch gel.

Anader yam chips

Fig. 4 shows the results of the sensory analysis of the different formulations of yam chips of the Anader variety compared with the control (without cassava gel coating). The results show that there were no significant differences (p>0.05) between the studied parameters of odor and appearance for all yam chips coated or uncoated with cassava starch gel. However, there was a significant difference (p<0.05) in the color and crispness parameters of the yam chips observed for the 2% and 4% cassava starch gel formulations. However, the results for these same parameters showed no significant difference (p>0.05) between control chips (without cassava gel coating) and chips coated with 2% and 3% cassava gel. Also, the results observed for control chips and chips coated with 3% and 4% cassava gel show no significant difference (p>0.05). The results obtained for the taste parameter show that there is a significant difference (p<0.05) for the 4% coated potato chips compared with the control potato chips (without cassava gel coating) and the 2% coated potato chips. On the other hand, 4% coated chips and 3%-coated chips showed no significant differences (p>0.05). Also, the results for control chips (without cassava gel coating) and chips coated with 2% and 3% cassava starch gel showed no significant difference (p<0.05) for the same parameter. Overall analysis of the sensory analysis data showed that panelists enjoyed the potato chips coated with 4% cassava starch gel. Fig. 5 shows Anader French fries uncoated with control and coated with 2%, 3% and 4% cassava starch gel.

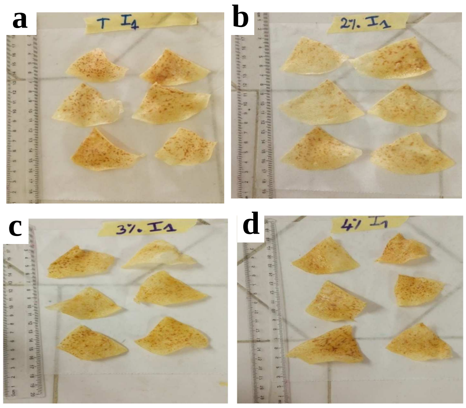

Fig. 3. a- Fried yam chips without coating (control), b- Fried yam chips coated with 2% gel, c- Chips coated with 3% cassava gel, d- Chips coated with 4% cassava gel

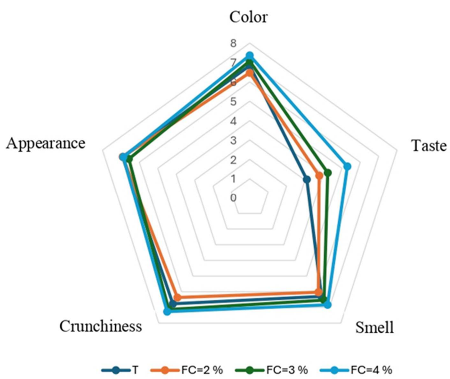

Fig. 4. Sensory profile of yam chips of the Anader variety (*D. cayenensis rotundata*)

T: uncoated yam chips (control); FC=2%: 2% coated yam chips; FC=3%: 3% coated yam chips; FC=4%: 4% coated yam chips.

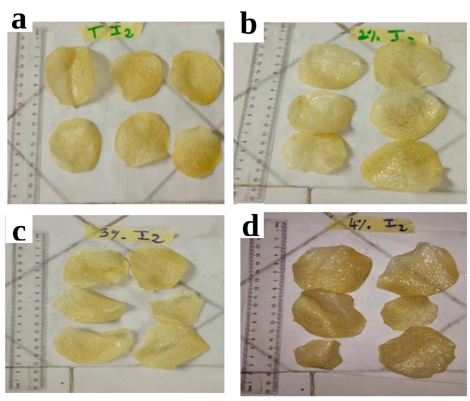

Fig. 5. a- Fried yam chips without coating (control), b- Fried yam chips coated with 2% gel, c- Fried yam chips coated with 3% gel, d- Fried yam chips coated with 4%

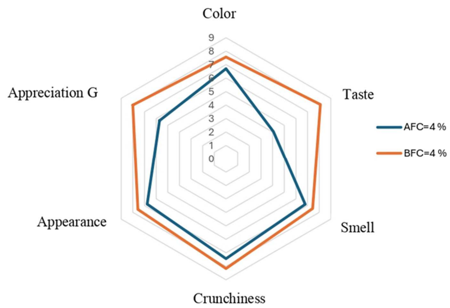

Fig. 6. Sensory profile of yam chips coated with 4% cassava gel of Bètè-Bètè variety (*D. alata*) and Anader variety (*D. cayenensis rotundata*)

AFC=4%: 4% coated Anader yam chips; BFC=4%: 4% coated Bètè-Bètè yam chips.

Sensory evaluation of the two most popular varieties of yam chips

The Bètè-Bètè and Anader chips coated with 4% were more appreciated by the sensory analysis panelists. The results of the sensory analysis of yam chips coated with 4% cassava starch gels most appreciated by panelists for the Bètè-Bètè variety and the Anader variety show no significant difference between the color, odor, crispness and appearance parameters between the two varieties of yam chips. On the other hand, the taste and general appreciation parameters showed a significant difference (p<0.05) for both varieties of potato chips. The Bètè-Bètè variety chips were more appreciated by panelists (Fig. 6).

Discussion

Color is one of the main quality factors of fried products. Significant differences were observed between the color parameter values of uncoated and coated chips of the different cassava starch-based gels irrespective of yam variety. Inter-variety comparison of color parameter values also showed a significant difference between coated and uncoated chips. In general, chips obtained with the Bètè-Bètè variety were more colorful ($a^* > 0$) than chips obtained with the Anader variety. The color of the chips is linked to the reducing sugar content of the raw material (Dewayani *et al.*, 2020). Indeed, during frying, the high temperature causes the Maillard reaction between reducing sugars and amino acids, which induces the coloring of the chips. The Maillard reaction being a non-enzymatic browning reaction occurring between reducing sugars and proteins at temperatures (Dewayani *et al.*, 2020). In this study, total and reducing sugar contents were higher in chips obtained with the Bètè-Bètè variety than those obtained with the Anader variety. This explains the difference in color parameters between the two varieties. The higher level of reducing sugars inevitably leads to browning of the chips during the frying process, as indicated by some authors (Wayumba *et al.*, 2019; Vaitkevičienė *et al.*, 2022). The differences observed in the color parameters of coated chips could be linked to the coating, which can protect certain amino acid reducing terminals in the product and slow down the non-enzymatic browning reaction (Hua *et al.*, 2015; Sumonsiri *et al.*, 2020).

Sensory evaluation was carried out on coated chips at different concentrations and on uncoated chips (control). The appearance parameter showed generally higher values for uncoated chips of both yam chip varieties. This may be due to poor color uniformity and irregularity of shape observed. This result was also reported by Vaitkevičienė *et al.* (2022), who assured that the coated chips had a different appearance due to the higher moisture content. Crispness is an important indicator for potato chips. Numerous studies have shown that maximum breaking strength is negatively related to crispness. Bourne *et al.* (1966) found that the lower the water content, the higher the crispness. The same observation was reported by Garcıa *et al.* (2002). Compared with control samples, the crispness of coated potato chips was higher. This could be attributed to the stickiness of starch gels and glycerol. Taste is the most important parameter in the sensory analysis of gel-coated and uncoated chips. The results of this study showed a significant difference between coated and uncoated cassava gel potato chips. Indeed, the higher the gel concentration, the better the taste. This could be due to the coating gel being a flavor factor in the chips (Trujillo-Agudelo *et al.*, 2020). In odor descriptors, coated yam chips showed higher qualification in good odor attributes for both coated and uncoated chip varieties. This is well perceived by the consumer. Color, on the other hand, showed no significant difference between coated and uncoated potato chips. These results are like those obtained by Trujillo-Agudelo *et al.* (2020) in their study. The comparison between varieties shows that the potato chips most appreciated by panelists are the 4% coated potato chips for both varieties. All parameters such as color, taste, smell, crispness, appearance and general appreciation were more appreciated for the coated potato chips of the Bètè-Bètè variety. This may be due to the starting composition of this yam variety.

Conclusion

The results of the study on the effect of cassava starch-based edible gel on the sensory and color properties of coated yam potato chips showed that the coating had a significant effect on the yam potato chips, as the coating enabled water to be retained in the potato chips and caused a considerable reduction in oil in the potato chips. The content of reducing and total sugars in the coated chips ensured good chip coloring, and the coating gave the chips a pleasant smell. Sensory analysis showed that Bètè-Bètè yam chips coated with 4% cassava starch gel were appreciated. Coating with cassava starch can be proposed as an alternative and effective method for reducing the oil content of chips.

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