Quality attributes of formulated snacks from blends of cassava starch and soy protein isolate deep fried in palmolein oil

Adebukola T. Omidiran1 | Olajide P. Sobukola1 | Silifat A. Sanni2 | Lateef O. Sanni1 | Abdul-rasaq A. Adebowale1 | Rukayat Azeez1 | Peter Iluebeya3

1Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria
2Department of Nutrition and Dietetics, Federal University of Agriculture, Abeokuta, Nigeria
3Cassava Breeding Unit, International Institute of Tropical Agriculture, Ibadan, Nigeria

Correspondence
Adebukola T. Omidiran, Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria. Email: omidiranat@funaab.edu.ng; omidiranat@gmail.com

Abstract
Cassava starches from three varieties (TMS-30572, TMS-950289 and TME-419) and soy protein isolate (SPI) were used to prepare dough at different proportions of 85:15 and 95:5 ratio of cassava starch to soy protein isolate. Dough were sheeted, cut and fried in palmolein oil at deep frying conditions of 170°C and 180°C for 5 and 15 min for temperature and time, respectively. Texture, chemical and colour properties were evaluated using a 2-level full factorial experimental design (23) for three factors. The data obtained were analysed using analysis of variance (ANOVA) and numerical optimization in design expert 6.0.8. There were significant (p < .05) effects on expansion, colour and appearance. The optimized SPI level, frying temperature and frying time of 15%, 170°C and 2 min were obtained for TMS-950289; 15%, 180°C and 4 min for TME-419; and 15%, 170°C and 4 min for TMS-30572, respectively.

1 | INTRODUCTION

Snack contributes an important part of many consumers' daily nutrient and calorie intake according to Bhattacharyya, Chakraborty, Chattorny and Makherjee (1997). Gradually, snacks are taking over the main portion of the meal due to the convenience and ready-to-eat status. They are produced mostly from locally available agricultural raw materials and other ingredients as needed to make it palatable, appealing and most importantly, nutritious. Consumer awareness has increased on the importance of eating products that are wholesome and healthy, with specific characteristics though with minimal oil content. Snacks have been produced from whole flour from different crops like wheat, cassava, soybean and maize, which contains the nutrients in all forms, some of which are needed in larger quantities than the other. Building of controlled structures in food products requires understanding the behaviour of the individual constituent prior to or during processing, and product formulation provides alternative method for new products with controlled quality attributes (Aguilera, 2006). ‘Formulated products based on cassava starch and soy protein isolate which is gluten-free could make it possible to investigate the effects of different product formulations on oil absorption, contributing to the understanding of the mechanisms that may be involved and its use in the production of fried products’ (Gazmuri & Bouchon, 2009). These structures will be controlled to enhance uniformity in food product and helps to have a better understanding of how each element functions before and during processing. Frying is an ancient preparation technique that impacts unique flavour and texture to food products that transcend from generation to generation. This makes fried snacks to be in high demand and appreciated by consumers, hence the reason why it is being extensively used in food processing. Tropical Manihot esculenta (TME) 419 also called NICASS 20 is a high dry matter (25%), high CMD resistance, high yielding (>25 t/ha), poundable and high starch cassava variety. Tropical Manioc Selection (TMS) 30,572 also called NICASS 1 is a high dry matter (25%), moderate CMD resistance, early bulking, high starch and high yielding (>25 t/ha), and TMS-950289 is an International...
Institute of Tropical Agriculture (IITA) clone, part of genetic gain collection as reported by IITA. Cassava starch has been reported to have low pasting temperature, low amylose content and a low tendency for syneresis when compared with other commercial starches. Soybean is known to be a dry powder food ingredient that has 90–95% protein and nearly carbohydrate and fat-free. The use of palmolein oil in frying snacks has been identified as a good oil as it does not emit undesirable odour, is highly resistant to oxidation, does not contain linolenic acid and has a favourable nutritional composition for being free of trans fatty acids and presenting tocopherols in its composition (Basiron, 2005). Omidiran et al. (2019) reported some findings on some characteristics of these formulated snacks deep fried in soybean oil. Hence, the objective of the study is to assess and optimize the quality attributes of fried snacks from cassava starch of different varieties and soy protein isolate (SPI) blends using palmolein oil.

2 MATERIALS AND METHODS

2.1 Materials

Fresh cassava roots of three varieties, namely, TMS-30572, TMS-950289 and TME-419, were obtained from Cassava Breeding Unit, International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. The cassava International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. The SPI was obtained from NutriChem, Ikeja, Lagos, Nigeria. Materials that include palmolein oil and packaging materials were obtained from stores at camp, Abeokuta, Ogun state.

2.2 Methods

2.2.1 Cassava starch preparation

Fresh cassava roots were harvested, and starch was extracted from the roots. Cassava starch was produced according to the method of Aseidu (1989). The cassava root was weighed immediately after harvesting from farm. The peeled cassava root was washed in water, the washed root was grated and the screened starch was allowed to settle and decanted. The final product was packaged in high density polyethylene (Ziploc).

2.2.2 Dough preparation

Preparation of the dough was carried out according to the modified method of Gazmuri and Bouchon (2009), by adding 152 ml of hot water (90–100 °C) to 85:15 of cassava starch to SPI for 200 g of the mixture. For 95:5, 140 ml of the hot water was added. The mixture was kneaded until a smooth dough was obtained, sheeted and cut with a cutter to get accurate shape (diameter 10 cm and thickness 0.25 cm).

2.2.3 Experimental design

A $2^3$ (two-level) full factorial in the design expert software was adopted to study the interactive effect of frying temperature (170 °C and 180 °C), frying time (2 and 4 min) and SPI level (5% and 15%) at two levels stated, on some quality attributes of the fried snacks and the experimental runs as presented in Table 1.

2.2.4 Atmospheric frying

Palmolein oil was preheated for 30 min; samples were then placed inside the frying basket of deep fat fryer (SAISHO, Model S-616, China) that was covered with a lid in order to ensure samples do not float in the frying oil during frying. Frying baskets were immersed into the oil at 170 °C and 180 °C for 2 and 4 min, and the fried snacks were removed and cooled after every batch. The fried snacks were then packaged in air-tight containers until further analyses.

2.3 Proximate composition of fried snacks samples

AOAC (2000) methodology was used to determine the proximate composition (total moisture content, crude fat, ash content) of the snacks. Protein content was analysed using Kjedahl method (AACC, 2000, 46-12.01). The carbohydrate content was obtained by calculating the difference from the sum total.

2.4 Sensory evaluation

Acceptance testing method of Meligaard, Civille and Carr (1999) was used to assess the sensory attributes (sweetness, expansion, crispness, oiliness, colour, appearance and overall acceptability) of the fried snacks prepared using the optimized frying conditions. A total of 50 untrained panelists, students of Federal University of Agriculture, Abeokuta that love eating snacks, participated in evaluating the snacks. The panelists were both male and female, age ranged between

| TABLE 1 | Experimental runs showing different combinations of the independent variables |
|---------|----------------------------------|
| Run | SPI (%) | Frying temp. (°C) | Frying time (min) |
| 1 | 5 | 170 | 2 |
| 2 | 5 | 170 | 4 |
| 3 | 5 | 180 | 2 |
| 4 | 5 | 180 | 4 |
| 5 | 15 | 170 | 2 |
| 6 | 15 | 170 | 4 |
| 7 | 15 | 180 | 2 |
| 8 | 15 | 180 | 4 |

Abbreviation: SPI, soy protein isolate.
analysed statistically. The mean values of scores for each of attributes were computed and exactly like very much = 2, dislike moderately = 3, dislike slightly = 4, neither like nor dislike = 5, like slightly = 6, like moderately = 7, like very much = 8 and like extremely = 9. The average and mean values of scores for each of attributes were computed and analysed statistically.

2.5 | Expansion analysis

The procedures of Maeda and Cereda (2001) were used in the determination of expansion. The diameter of each dough was measured with a Vernier calliper before and after frying. Frying expansion capacity was calculated by relation between the initial average diameter of the dough before frying and their final average diameter after frying.

2.6 | Texture analysis

The textural parameters (Chewiness [N] and Hardness [N]) of the fried snacks were measured using a Universal Testing Machine (Model: M500-100AT, Capacity: 100 kN, Stable Micro Systems Ltd., Godalming, Surrey, UK). A 3-point bending test was used with the sample supported at two parallel edges and the load applied centrally. Results for hardness and chewiness were obtained by placing fried snacks on the texture analyser, and the mean of three measurements for each frying condition was reported (Da Silva & Moreira, 2008).

2.7 | Colour analysis

The colour parameters of the fried snacks were measured using a Konica Minolta Colour Measuring System (Chroma meter CR-410, Minolta LTD, Japan) according to the procedures of Mariscal and Bouchon (2008). The lightness (L*), redness (a*) and yellowness (b*) values were obtained. Four replicate readings were taken for each fried snack and the average value reported. The results were expressed in accordance with the CIELAB system, where

L* is known as the lightness (L = 0 [black], L = 100 [white]), a* (−a = greenness, +a = redness), b* (−b values = blueness, +b* value = yellowness).

2.8 | Data analysis

Data obtained were analysed using analysis of variance (ANOVA) to determine significant effect on the responses at 5% level, and models were generated showing the relationship between the independent variable and the responses using Design Expert version 6.0.8.

3 | RESULTS AND DISCUSSION

3.1 | Chewiness and hardness

Table 2 presents the results of chewiness and hardness of samples from TMS-950289, and they ranged from 1.17 to 235.56 N and 4.68 to 987.65 N, respectively. Run 7 (15% SPI/180°C/2 min) had the highest value (235.56 N for chewiness and 987.65 N for hardness), whereas Run 3 with 5% SPI/180°C/2 min had the least value (1.17 N) for chewiness. The coefficient of determination of the model developed for chewiness and hardness was 0.9443 and 0.9950, where F value is 2.83 and 3.53, respectively, as presented in Table 5. It was observed that increased frying temperature, increased SPI and decreased frying time led to an increase in chewiness value. The mean value of chewiness and hardness for samples from TME-419 (Table 3) ranged from 3.84 to 24.06 N and 8.76 to 147.66 N, respectively. Run 8, corresponding to 15% SPI/180°C/4 min, had the highest value (24.06 N), whereas Run 6 with 15% SPI/170°C/4 min had the least value (3.84 N). From Table 6, the coefficient of determination (R²) of the model developed for chewiness and hardness was 0.95 and 0.99 and F value of 2.92 and 30.96, respectively. From the values obtained, increased frying temperature, frying time and a decreased SPI level resulted in increased chewiness value. However, an increase in SPI, decreased frying time and frying temperature resulted in a decreased chewiness value. Table 4 presents the mean value of chewiness and hardness from TMS-30572, which ranged from 0.99 to 137.78 and 26.39 to 758.65, respectively. Run 4, corresponding to 5% SPI/180°C/4 min, had the highest value (137.78) for chewiness, whereas Run 3 with 5% SPI/180°C/2 min had the least value (0.09). From Table 7, the model developed had a coefficient of determination (R²) of chewiness, and hardness was 0.76 and 0.82 and the F value of 0.53 and 0.75, respectively. It was also observed that increased SPI level, frying time and frying temperature resulted into a decreased hardness and chewiness value, whereas highest chewiness value was obtained at an increased frying temperature, decreased frying time and SPI level. Increased hardness value was observed at a decreased frying temperature and increased frying time and SPI level. This model gives an insight into how to combine the various processing conditions to suit the nature of the snacks to be produced. Increase in hardness value could be attributed to the lower moisture of the product.

3.2 | Expansion analysis

The mean value for expansion ranged from 4.86 to 10.8 mm, 4.53 to 11.08 mm and 4.51 to 10.93 mm for snacks from TMS-950289, TME-419 and TMS-30572, respectively, whereas the coefficient of determination and F value were 0.87 and 1.08, 0.48 and 0.16 and 0.97 and 4.91, respectively. Maximum expansion value was observed at an increased frying temperature and frying time and a decreased SPI level. This could be due to the fact that SPI and cassava starch do not contain gluten, which supports maximum
TABLE 2  Mean values of the responses at different experimental runs for TMS-950289 sample

| Run | SPI (%) | Frying temp. (°C) | Frying time (min) | Chewiness (N) | Hardness (N) | Expansion (mm) | Lightness (L*) | Redness (a*) | Yellowness (b*) | Protein (%) | Oil (%) | Moisture (%) |
|-----|---------|-------------------|------------------|---------------|--------------|---------------|---------------|-------------|----------------|-------------|---------|-------------|
| 1   | 5       | 170               | 2                | 3.72          | 4.68         | 4.86          | 68.06         | −1.06       | 13.81          | 6.12        | 10.85   | 16.79       |
| 2   | 5       | 170               | 4                | 12.90         | 59.40        | 10.80         | 70.29         | −0.07       | 16.03          | 3.28        | 10.03   | 13.55       |
| 3   | 5       | 180               | 2                | 1.17          | 67.83        | 9.29          | 69.16         | 0.25        | 15.08          | 4.66        | 9.02    | 13.86       |
| 4   | 5       | 180               | 4                | 8.63          | 146.39       | 10.66         | 64.13         | 0.47        | 15.19          | 4.72        | 7.13    | 13.46       |
| 5   | 15      | 170               | 2                | 34.68         | 91.61        | 9.04          | 67.96         | 1.33        | 19.54          | 5.28        | 9.67    | 13.07       |
| 6   | 15      | 180               | 4                | 2.81          | 34.72        | 7.21          | 67.11         | 1.00        | 21.36          | 5.68        | 9.05    | 12.54       |
| 7   | 15      | 180               | 2                | 235.56        | 987.65       | 6.49          | 65.68         | 0.47        | 14.09          | 5.46        | 8.97    | 12.49       |
| 8   | 15      | 180               | 4                | 61.28         | 422.93       | 6.12          | 64.65         | 1.08        | 18.56          | 5.90        | 9.27    | 14.02       |

Abbreviation: SPI, soy protein isolate.

TABLE 3  Mean values of the responses at different experimental runs for TME-419 sample

| Run | SPI (%) | Frying temp. (°C) | Frying time (min) | Chewiness (N) | Hardness (N) | Expansion (mm) | Lightness (L*) | Redness (a*) | Yellowness (b*) | Protein (%) | Oil (%) | Moisture (%) |
|-----|---------|-------------------|------------------|---------------|--------------|---------------|---------------|-------------|----------------|-------------|---------|-------------|
| 1   | 5       | 170               | 2                | 7.44          | 9.47         | 4.53          | 67.92         | −1.00       | 14.58          | 1.76        | 10.56   | 17.03       |
| 2   | 5       | 170               | 4                | 18.04         | 65.79        | 9.49          | 64.74         | −0.14       | 15.28          | 5.68        | 11.04   | 14.37       |
| 3   | 5       | 180               | 2                | 6.78          | 147.66       | 11.08         | 66.00         | −0.01       | 15.53          | 5.07        | 10.33   | 15.50       |
| 4   | 5       | 180               | 4                | 21.66         | 112.89       | 8.23          | 64.74         | −0.14       | 15.28          | 5.68        | 11.04   | 14.37       |
| 5   | 15      | 170               | 2                | 6.18          | 8.76         | 7.64          | 72.10         | 1.09        | 15.08          | 2.74        | 11.02   | 13.94       |
| 6   | 15      | 170               | 4                | 3.84          | 90.15        | 7.31          | 58.76         | 2.50        | 22.94          | 5.80        | 9.45    | 11.10       |
| 7   | 15      | 180               | 2                | 8.40          | 20.79        | 5.63          | 59.54         | 2.08        | 21.73          | 1.31        | 10.78   | 13.82       |
| 8   | 15      | 180               | 4                | 24.06         | 89.09        | 8.65          | 53.45         | 3.29        | 24.35          | 6.12        | 7.67    | 12.82       |

Abbreviation: SPI, soy protein isolate.
expansion, hence its maximum value at a reduced SPI level. Gazmuri and Bouchon (2009) reported that gluten content was the most significant factor determining product expansion in predried discs of wheat gluten and starch matrices during deep-fat frying. Expansion was not significantly affected by the processing when fried in palmolein oil.

3.3 | Colour parameters

The mean value for Lightness of sample (Tables 2–4) ranged from 64.13 to 70.29, 53.45 to 72.10 and 59.28 and 74.33; redness ranged from −1.06 to 1.33, −1.00 to 3.29 and −0.87 to 1.72; and yellowness ranged from 13.81 to 21.36, 15.02 to 24.35 and 14.44 and 21.78 for snacks from TMS-950289, TME-419 and TMS-30572, respectively. The coefficient of determination and F values were 0.81 and 0.71, 0.99 and 11.01 and 0.82 and 0.78 for lightness; 0.97 and 6.01, 0.99 and 37.25 and 0.99 and 95.06 for redness; and 0.95 and 3.00, 0.97 and 6.22 and 0.99 and 1959.25 for yellowness, respectively. Increase in frying time but decrease in frying temperature and SPI level led to an increase in lightness, and a decrease in frying time, frying temperature and SPI caused a decrease in redness and yellowness value. The main effect of SPI level significantly (p < .05) affected the redness of the samples from TME-419 and TMS-30572 positively. The main effect of frying temperature, frying time, SPI level and the interaction between frying temperature and SPI level significantly (p < .05) affected the yellowness of the samples from TMS-30572 positively. Changes observed in the colour of fried snacks could be due to Maillard reactions taking place, and this depends on the content of reducing sugars and amino acids at the surface, the temperature and the frying time as reported by Dueik and Bouchon (2011). L* is the first critical parameter used in determining product acceptance by consumers, and dark-coloured snacks are associated with non-enzymatic browning reactions as a result of low L* values.

3.4 | Protein content

Protein content of the sample ranged from 3.28% to 6.12%, 1.31% to 6.12% and 3.06% to 6.36% for snacks from TMS-950289, TME-419 and TMS-30572, respectively. The model developed had a coefficient of determination (R²) of 0.82 and F value of 0.78 for TMS-950289, 0.68 and 0.35 for TME-419 and 0.99 and 60.52 for TMS-30572. Increased protein value corresponds to an increased frying temperature, frying time and SPI for TMS-950289 but an increased frying time, SPI with decreased frying temperature for TME-419 and TMS-30572. It can be observed that the content of protein present in the fried snacks is due to percentage of the SPI level. An increase in SPI level results in increase in protein content and vice versa. Felberg et al. (2004) found an average protein concentration for a soybean-based beverage produced from soybean extract.
**TABLE 5**  Regression coefficient of the response as a function of independent variables for TMS-950289 sample

| Parameters | Chewiness (N) | Hardness (N) | Expansion (mm) | Lightness (L') | Redness (a') | Yellowness (b') | Protein (%) | Oil (%) | Moisture (%) |
|------------|---------------|--------------|----------------|---------------|--------------|-----------------|-------------|---------|--------------|
| Intercept  | 45.09         | 226.65       | 8.06           | 67.13         | 0.35         | 16.71           | 5.14        | 9.25    | 13.72        |
| A—frying time | 31.57        | 179.05       | 0.081          | -1.23         | 0.22         | -0.98           | 0.047       | -0.65   | -0.26        |
| B—frying temp | -23.69       | -60.79       | 0.64           | -0.59         | 0.10         | 1.08            | -0.24       | -0.38   | -0.33        |
| C—SPI    | 38.49         | 157.08       | -0.84          | -0.78         | 0.62         | 1.68            | 0.44        | -8.750E-003 | -0.69        |
| AB       | -18.02        | -60.25       | -0.39          | -0.93         | 0.10         | 0.067           | 0.37        | -0.019  | 0.61         |
| AC       | 33.27         | 141.52       | -0.99          | 0.040         | -0.41        | -1.08           | 0.053       | 0.53    | 0.49         |
| BC       | -27.85        | -94.11       | -1.19          | 0.12          | 0.034        | 0.49            | 0.45        | 0.30    | 0.58         |
| R²       | 0.9443        | 0.9550       | 0.8661         | 0.8096        | 0.9730       | 0.9473          | 0.8243      | 0.9382  | 0.9941       |
| F value  | 2.83          | 3.53         | 1.08           | 0.71          | 6.01         | 3.00            | 0.78        | 2.53    | 28.23        |

Note: A = frying temperature, B = frying time, C = level of SPI. Abbreviation: SPI, soy protein isolate.  
*Significant at 5% level.

**TABLE 6**  Regression coefficient of the responses as a function of independent variables for TME-419 sample

| Parameters | Chewiness (N) | Hardness (N) | Expansion (mm) | Lightness (L') | Redness (a') | Yellowness (b') | Protein (%) | Oil (%) | Moisture (%) |
|------------|---------------|--------------|----------------|---------------|--------------|-----------------|-------------|---------|--------------|
| Intercept  | 12.05         | 55.57        | 7.82           | 63.40         | 0.96         | 18.18           | 3.83        | 10.07   | 13.93        |
| A—frying time | 3.18          | 12.03        | 0.58           | -2.48         | 0.35         | 1.21            | -0.16       | -0.45   | -0.18        |
| B—frying temp | 4.85          | 33.90        | 0.60           | -2.99         | 0.42         | 1.15            | 1.11        | -0.61   | -1.14        |
| C—SPI    | -1.43         | -3.38        | -0.51          | -2.44         | 1.28*        | 2.85            | 0.16        | -0.34   | -1.01        |
| AB       | 2.79          | -0.52        | -0.56          | 1.14          | -0.15        | -0.69           | 0.63        | -0.33   | 0.23         |
| AC       | 2.43          | -9.29        | -0.74          | -1.99         | 0.095        | 0.81            | -0.11       | -0.052  | 0.58         |
| BC       | -1.52         | 3.52         | 0.072          | -1.87         | 0.23         | 1.17            | 0.85        | -0.56   | 0.18         |
| R²       | 0.9460        | 0.9946       | 0.4843         | 0.9851        | 0.9955       | 0.9739          | 0.6801      | 0.9978  | 0.9815       |
| F value  | 2.92          | 30.96        | 0.16           | 11.01         | 37.25        | 6.22            | 0.35        | 74.49   | 8.87         |

Note: A = frying temperature, B = frying time, C = level of SPI. Abbreviation: SPI, soy protein isolate.  
*Significant at 5% level.

**TABLE 7**  Regression coefficient of the response as a function of independent variables for TMS-30572 sample

| Parameters | Chewiness (N) | Hardness (N) | Expansion (mm) | Lightness (L') | Redness (a') | Yellowness (b') | Protein (%) | Oil (%) | Moisture (%) |
|------------|---------------|--------------|----------------|---------------|--------------|-----------------|-------------|---------|--------------|
| Intercept  | 34.36         | 169.54       | 7.74           | 64.17         | 0.52         | 17.61           | 4.80        | 9.85    | 14.06        |
| A—frying time | 8.95          | 54.93        | 0.045          | -1.17         | 0.35         | 0.44*           | 0.22        | -0.49   | -0.90        |
| B—frying temp | -26.10        | -83.87       | 1.56           | 0.95          | 0.12         | 0.83*           | 0.22        | -0.49   | -0.90        |
| C—SPI    | -7.79         | -65.30       | -1.22          | -3.50         | 0.63*        | 2.37*           | -0.81       | -0.16   | -6.250E-003 |
| AB       | -14.99        | -103.69      | 0.49           | -0.88         | -0.043       | 0.12            | -0.74       | 0.18    | 0.31         |
| AC       | -17.82        | -102.75      | 0.52           | 0.45          | -0.18        | 0.32*           | 0.25        | -0.040  | -0.78        |
| BC       | 6.67          | 81.83        | 0.055          | -1.31         | 0.36         | 0.064           | 0.50        | -0.37   | 0.71         |
| R²       | 0.7600        | 0.8189       | 0.9672         | 0.8240        | 0.9982       | 0.9999          | 0.9973      | 0.5707  | 0.9810       |
| F value  | 0.53          | 0.75         | 4.91           | 0.78          | 95.06        | 1959.25         | 60.52       | 0.22    | 8.61         |

Note: A = frying temperature, B = frying time, C = level of SPI.  
Abbreviation: SPI, soy protein isolate.  
*Significant at 5% level.
3.5 | Oil content

Oil absorption is a critical parameter affecting the quality, appearance and colour of fried food. The mean value for oil content ranged from 7.13% to 10.85%, 7.67% to 11.04% and 8.12% to 11.33% for snacks from TMS-950289, TME-419 and TMS-30572, respectively. The model developed had a coefficient of determination ($R^2$) of 0.94 and $F$ value of 2.53 for TMS-950289, 0.99 and 74.49 for TME-419 and 0.57 and 0.22 for TMS-30572. The minimum oil content corresponds to an increased frying temperature, frying time and decreased SPI level. Bouchon and Pyle (2004) reported that stronger and more elastic network can result in a less permeable outer layer that may act as an effective barrier against oil absorption. After the food has been dried completely and removed from the fryer, the product begins to cool, and water vapour condenses with a consequent decrease in internal pressure. Dana and Saguy (2006) reported that the mechanism of oil absorption occurs during the cooling phase, and this is known as cooling effect. Decrease in oil content observed could be due to the fact that the snacks were formulated from starch and protein constituents, and the surface oil was removed during cooling to prevent further uptake.

3.6 | Moisture content

The mean values of moisture content of samples ranged from 12.49% to 16.79%, 11.10% to 17.03% and 11.84% to 17.31% for snacks from TMS-950289, TME-419 and TMS-30572, respectively. The model developed had a coefficient of determination ($R^2$) of 0.99 and $F$ value of 28.23 for TMS-950289, 0.98 and 8.87 for TME-419 and 0.98 and 8.61 for TMS-30572. The minimum moisture content corresponds to an increased frying time and SPI at a reduced frying temperature. Akubo (1997) reported that the lower the moisture content of a product, the better the storage stability of the product. Ngadi, Watts and Correia (1997) stated that the rate of moisture removal is directly related to frying time and frying temperature. Increased frying temperature and time caused a decrease in the moisture content value of the fried snacks. The values obtained suggested that the frying condition reduces the final moisture contents of some of the fried snacks to below the minimum value recommended for shelf stable products.

3.7 | Optimization of process variables

Chewiness, expansion, yellowness and protein content were maximized for each varieties, whereas hardness, lightness, redness, oil content and moisture content were minimized. SPI level of 15%, frying temperature of 170°C and frying time of 2 min, with a desirability of 0.435 were selected for TMS-950289; SPI level of 15%, frying temperature of 180°C and frying time of 4 min, with a desirability of 0.463 were selected for TME-419; 15% SPI level, frying temperature of 170°C and frying time of 4 min, with a desirability of 0.501 were selected for TMS-30572, and an optimized sample was prepared under these conditions.

3.8 | Sensory evaluation

The result of sensory evaluation is presented in Figure 1 showing the relationship of the optimized fried snacks, based on their attributes. All the samples were found to be moderately acceptable by the panellists because their scores were above average with overall acceptability rating ranged from 6.17 to 7.53. The sample (TME-419) was rated highest in terms of sweetness (6.67), crispness (7.47), oiliness (7.43), colour (7.27) and overall acceptability (7.53). There were no significant ($p < .05$) differences observed for expansion, colour and appearance. However, significant ($p < .05$) differences were observed in terms of sweetness, crispness and oiliness and overall acceptability of the samples.

4 | CONCLUSION

Inclusion of SPI significantly affected the redness of snacks produced from TME-419 and TMS-30572 samples positively. The frying time, frying temperature and SPI percent significantly affected the yellowness value of TMS-30572 sample positively, whereas other quality attributes had no significant effect. Optimized SPI level of 15%, frying temperature of 170°C and frying time of 2 min were obtained for TMS-950289; SPI level of 15%, frying temperature of 180°C and frying time of 4 min were obtained for TME-419; and SPI level of 15%, frying temperature of 170°C and frying time of 4 min were obtained for TMS-30572. The varieties of cassava had significant effect at 5% on expansion, colour and appearance of the fried snacks. TME-419
had the highest overall acceptability. TME-419 had the lowest oil content, highest expansion and chewiness. Fried snacks produced from TMS-950289 had the most preferable quality attributes at frying temperature of 170°C, frying time of 2 min and SPI of 5%.

ACKNOWLEDGEMENTS
The effort of Cassava Breeding Unit, IITA, Nigeria is acknowledged and appreciated for the provision of cassava roots used and laboratory space for processing into starches. Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria is also acknowledged for their support.

CONFLICT OF INTEREST
No conflict of interest was declared by the authors.

ETHICS STATEMENT
I hereby declare that this manuscript has not been published elsewhere, there is no conflict of interest and all coauthors met the criteria for authorship. The study does not require any ethical approval. If any error is subsequently found in the manuscript, I will inform the journal.

AUTHOR CONTRIBUTIONS
Adebukola T. Omidiran, Olajide P. Sobukola, Lateef O. Sanni, Silifat A. Sanni and Abdulrasaq A. Adebowale were involved in the conception and design of the work, data analysis and interpretation. Rukayat Azeez and Adebukola T. Omidiran collected data and drafted the article. Peter Bluebey provided the research samples and and laboratory use for starch production. Critical revision of the article was carried out by Adebukola T. Omidiran and Olajide P. Sobukola.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

FUNDING INFORMATION
The study was self-funded.

ORCID
Adebukola T. Omidiran https://orcid.org/0000-0001-6659-7506
Abdul-rasaq A. Adebowale https://orcid.org/0000-0003-1464-7190

REFERENCES
AACC. (2000). Approved Methods of American Association of cereal Chemists (Vol. 1 (method No. 30–35, 44–15A)). St. Paul/Minnesota, USA: Association of Cereal Chemists.

Aguilera, J. M. (2006). Food products engineering: Building the right structures. Journal of the Science of Food and Agriculture, 86(8), 1,147–1,155.

Akubo, P. I. (1997). Proximate composition and selected functional properties of African breadfruit and sweet potato flour blends. Journal of Plant Foods Human Nutrition, 51, 53–60.

AOAC. (2000). Official Methods of Analysis of AOAC Intl (17th ed. Method No. 934.06). Washington, DC, USA: Association of Official Analytical Chemists.

Aseidu, T. J. (1989). Processing Tropical Crops (pp. 1–22). London: Macmillan Edu. Ltd.

Basiron, Y. (2005). Palm oil. In F. Shahidi (Ed.), Bailey’s industrial oil and fat products (Vol. 2). New Jersey: John Wiley and Son. cap.8

Bhattacharyya, S., Chakraborty, P., Chattotry, D. K., & Makherjee, S. (1997). Physicochemical characteristics of extruded snacks prepared from rice and chickpea by single screw extruder. Journal of Food Science and Technology, 34, 320–323.

Bouchon, P., & Pyle, D. L. (2004). Studying oil absorption in restructured potato chips. Journal of Food Science, 69(3), FEP115–FEP122.

Da Silva, P., & Moreira, R. (2008). Vacuum frying of high-quality fruit and vegetable based snacks. Lebensmittel- Wissenschaft and Technology, 22, 535–548.

Dana, D., & Saguy, I. S. (2006). Review: Mechanism of oil uptake during deep-fat frying and the surfactant effect-theory and myth. Advance in Colloid and Interface Science, 128–130, 267–272.

Dueik, V., & Bouchon, P. (2011). Development of healthy low-fat snacks: Understanding the mechanisms of quality changes during atmospheric and vacuum frying. Food Reviews International, 27, 408–432.

Felberg, I., Deliza, R., Goncalves, E. B., Antoniassi, R., Freitas, S. C., & Cabral, L. C. (2004). Bebida mista de extrato de soja integral e creme de banana. Alimentos and Nutricao, 5, 163–174.

Gazmuri, A., & Bouchon, P. (2009). Analysis of wheat gluten and starch matrixes during deep fat frying. Food Chemistry, 115, 999–1005.

Maeda, K. C., & Cereda, M. P. (2001). Evaluation of two methods of expansion of the oven sour, research center for Tropical Roots and Starches, Cerat Brazil. https://doi.org/10.1590/s0101-20612001000200003

Mariscal, M., & Bouchon, P. (2008). Comparison between atmospheric and vacuum frying of apple slices. Food Chemistry, 107(4), 1561–1569.

Meilgaard, M., Civille, G. V., & Carr, B. T. (1999). Affective tests: Consumer tests and in-house panel acceptance tests. In Sensory Evaluation Techniques (3rd ed.) (pp. 242–243). New York: CRC Press.

Ngadi, M. O., Watts, K. C., & Correia, L. R. (1997). Finite element method for moisture transfer in chicken drum during deep-fat frying. Journal of Food Engineering, 32(1), 11–20.

Omidiran, A. T., Sobukola, O. P., Sanni, S. A., Sanni, L. O., Adebowale, A. A., Shajobi, O. A., & Kulakow, P. (2019). Evaluation of some quality parameters of cassava starch and soy protein isolate matrices during deep fat frying in soybean oil. Journal of Food Science and Nutrition, 7, 656–666.

How to cite this article: Omidiran AT, Sobukola OP, Sanni SA, et al. Quality attributes of formulated snacks from blends of cassava starch and soy protein isolate deep fried in palmolein oil. Legume Science. 2020;2:e61. https://doi.org/10.1002/leg3.61