



Original Article

Influence of frying parameters and cooking oil type on the physicochemical composition of used cooking oil in bitter yam chips production

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ABSTRACT

Bitter yam is an underutilized but nutrient-dense tuber, and it has the potential of being converted to value-added bitter yam chips through the deep fat frying technique. This study aimed to investigate the influence of frying temperature, frying cycle and cooking oil type on the physicochemical composition of used cooking oil in bitter yam chips production. Response surface methodology was used to interact the effect of frying temperature (170°C, 180°C, 190°C), frying cycle (1st, 2nd and 3rd cycle) and cooking oil type (soybean oil, coconut oil and peanut oils) on the viscosity, peroxide value, colour (L^* , a^* and b^*), iodine value, free fatty acid (FFA), p-anisidine, saponification value and refractive index of the used cooking oil. The frying cycle significantly influenced the viscosity, peroxide value, iodine value, L^* , b^* , FFA and p-anisidine of the used cooking oil. The quadratic effect of cooking oil type affected the a^* while the quadratic effect of the frying cycle influenced the refractive index of the used cooking oil. The used coconut oil had the highest viscosity (78.74), peroxide value (3.23), iodine value (80.10) and saponification value (203.21). However, the used peanut oil had the highest L^* (25.39), p-anisidine (3.44), and refractive index (1.52) while soybean oil had the highest a^* (-4.40), b^* (1.60) and FFA (62.16) at varied frying conditions. This information would be valuable to producers of bitter yam chips on cooking oil reusability.

1. Introduction

Frying is a typical cooking method used industrially and in homes around the world for food production [1]. Frying may cause chemical changes in the medium used for frying. However, these chemical reactions are not volatile but may affect the physical properties of the frying container [2]. A series of chemical changes occur when food products are fried. Some of these changes are due to reactions like oxidation, hydrogenation, isomerization and hydrolysis. When frying items in heated oil, water evaporates with bubbles and the vapour created in the product gradually decreases during the frying process [3].

The oil used for frying can have its stability affected by temperature and frying duration, composition and oxygen availability [4]. When these oils are repeatedly used, they tend to become more viscous as the frying cycle increases. In addition, the nature of the product, oil residence time, and type of oil affect their absorption into food products during frying [1].

Oils extracted from coconut, peanut, and soybean aid food processing. The heating and processing of food from these kinds of oil or fat above the boiling temperature of water are called deep-frying. Deep-frying

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allows mass transfer in two directions within the fried material- water and soluble components exit while oil enters the food (plant-based or starchy food [5]. Plant-based oil such as vegetable oils are triglycerides obtained from different pressing methods by extracting oil from plants containing seeds (e.g., cottonseed, palm kernel and soybean), fruits or nuts. These oils aid the transport of fat-soluble vitamins, and they release energy in the body [6,7]. In soybean oil, the fatty acid (FA) is about 85% unsaturated [8]. Josephine et al. [7] are of the opinion that this high unsaturated FA content and smoke point of 460°F (210°C) make soybean oil the best frying oil. Soybean oil is cheap and rich in plant protein [9][10]. It is also a rich source of unsaturated FA [11]. Peanut oil is extracted from peanuts seeds which contain a high amount of polyunsaturated FA and high antioxidants. These antioxidants reduce blood cholesterol and help fight infections. However, when subjected to heat treatment, the physicochemical properties of peanut oil become affected [12][13][14]. Other oil like coconut oil, extracted through a cold or hot process contain medium-chain FA also beneficial for the body [15]. Coconut oil is extracted from matured coconut kernel, and it has diverse nutritional and microbial inhibition benefits. Coconut oil aids body cell growth and tissue regeneration [16].

Cooking oils when freshly produced are suitable for frying. The FA and nutrients present in a freshly produced oil are of health benefits. However, used cooking oil is a waste derived from oil types like soybean oil, peanut oil and sunflower oil [17]. Oil subjected to high temperatures during frying can undergo many chemical distortions in its triglyceride contents. These chemical reactions form toxic chemicals in the oil that further reduce the oil quality, especially when these oils are repeatedly used. It is important to understand the adverse effect of consuming these types of oils. In Nigeria, the consumption of overused cooking oil to save costs is common, leading to detrimental health issues. According to Leong *et al.* [18], eating the oil or the products from them can severely expose one to major health issues like diabetes, high blood pressure and other diseases. Cooking oil reuse could degrade its lipid contents, damage antioxidants and enhances the reactive degeneration of oxygen in the oil [18]. These repeated usages reduce costs and optimize profits with no regard for quality [19]. Therefore, this study aimed to investigate the influence of frying temperature, frying cycle and cooking oil type on the physicochemical composition of oil used in the production of bitter yam chips due to a sparse study on this.

2. Materials and Methods

2.1 Sample Collection

The coconut oil was purchased from the Iseyin market in Oyo state, Nigeria. Peanut and soybean oils were purchased respectively at Ipata market and tipper garage in Ilorin, Kwara State, Nigeria. Bitter yam was purchased from Ajegunle market, Oyo state, Nigeria. Figure 1 shows the recyclable deep fat fryer, samples of oils and bitter yam used for the experiment.



Fig 1. Recyclable deep fat fryer, oil types and bitter yam samples (left to right)

2.2. Experimental Design and Arrangement

The experiment was conducted at the Department of Food Engineering, University of Ilorin. The experimental design and layout are presented in Table 1. Response Surface Methodology (RSM) was used for the research experimental design layout. The factors taken into consideration were oil types (O), frying temperatures (T) and the number of cycles (C).

There are three levels for each of the factors, which are: Oil types - Coconut oil (CO), Peanut oil (PO) and Soybean oil (SO). Frying temperature – 170°C, 180°C, 190°C and Number of cycles - (1st, 2nd and 3rd). Table 1 illustrates the properties and the reference methods.

Table 1: Interactive design of the study variables using the Face Center Design of RSM

S/N	Oil Type	Frying Temp. (°C)	Frying Cycle
1	CO	170	1
2	SO	170	1
3	CO	190	1
4	SO	190	1
5	CO	170	3
6	SO	170	3
7	CO	190	3
8	SO	190	3
9	CO	180	2
10	SO	180	2
11	PO	170	2
12	PO	190	2
13	PO	180	1
14	PO	180	3
15	PO	180	2

Where CO is coconut oil, PO is peanut oil, and SO is soybean oil.

2.3. Experimental Procedure

2.3.1. Initial Analysis

Fifteen milligrams (15ml) samples of the coconut, soybean and peanut oils were collected to analyze their initial physicochemical properties.

2.3.2. Sample Preparation

The bitter yams were washed, peeled, rewashed, cut, weighed and washed before frying. The yams were ripe, white tubers beneath their bark-like skin. The average weight of the yam fried per cycle was 600 g. The quantity of oil used per cycle was 5 litres. A constant average thickness of bitter yam used in the experiment was 1cm thick and 5 cm long.

2.3.3. Cooking Test

The samples were pierced with a fork to ascertain that it was fully cooked. If the fork goes through the yam completely, the yam was cooked, and the frying time was recorded.

2.3.4. Oil Collection

The recyclable deep-fat fryer was used for the frying operation. After frying, the oil was passed into the cooling unit and left to cool for 10 minutes, 15 ml of the cooled oil was collected for the physicochemical analysis.

2.3.5. Pre-cleaning and After-cleaning Method

Before frying, the deep fat fryer was cleaned thoroughly with soap solution, passed through the connecting pipe to clean the cooling chambers, rinsed and left for 30 minutes to cool. After frying with one oil sample, the deep fryer was rinsed with the next oil type to be used, which was passed through the connecting pipe down to the cooling chamber to flush out residues of the used oil from the fryer.

2.4. Determination of Physicochemical Composition

The physicochemical compositions of the oil samples were determined in the laboratory using Firestone *et al.* [20] nutritional guidelines. The physicochemical composition determined were viscosity, peroxide value, colour (L^* , a^* and b^*), iodine value, FFA, p-anisidine, saponification value and refractive index.

2.4.1. Data Analysis

All the oil samples were conducted in duplicates. The descriptive, analysis of variance (ANOVA) and the posthoc analyses were done using the statistical package for social sciences (SPSS 20.0).

3. Results and Discussion

3.1. Viscosity

The high viscosity (resistance to flow) of vegetable oils is not desired in oil [21]. The effect of cooking oil type, frying temperature and frying cycle showed that the viscosity ranged from 0.90 - 78.74 as shown in Table 2. Coconut oil is the most viscous oil while the frying cycle and quadratic interaction effect of cooking oil type were observed to have the most significant effect at $p \leq 0.05$ on the viscosity (Tables 2 and 3). The results show a decline in oil viscosity as the temperature increases. The increased temperature and frying cycle decreased the viscosity of the oil. This observation could result from oil thermal degradation and polymerization [22][23]. Therefore, a reduced level of viscosity elevates unsaturation, which is a desirable quality of cooking oil. An increased oil unsaturation increases triglyceride FA chain lengths [24].

3.2. Peroxide Value

The Nigerian National Agency for Food Drugs Administration and Control (NAFDAC) benchmarked the peroxide value of soybean and peanut oils to be less than 10 milli-equivalents [25]. An increase in peroxide value in unsaturated fats and oils is an early indicator of rancidity [26]. The initial peroxide values are 0.886, 0.975, and 0.895 for soybean oil, peanut oil and coconut oil, respectively. The effect of cooking oil type, frying temperature and frying cycle showed that the peroxide values ranged from 2.01 to 3.23 as shown in Table 2. The ANOVA (Table 4) suggests that the frying cycle, the quadratic effect of the frying cycle and the interaction effect of the frying temperature and frying cycle significantly affect the peroxides values of the oil (at $p \leq 0.05$). In this study, coconut has the highest peroxide value at 190°C frying temperature in the 3rd frying cycle (Table 2). This could result from its high composition of unsaturated oil which makes it easily oxidized during thermal treatment [27]. The study also shows that the peroxide values of the oils increase as the frying cycle increases. This peroxide increment may be from the unstable nature of peroxide and the thermal degradation of oil during heating [28].

3.3. Iodine Value

Low Iodine value is a desirable quality of cooking oil [29]. According to NAFDAC regulations, the acceptable range for iodine values of soybean, coconut and peanut oils respectively are (124-139), (6.3-10.6) and (77-107) while codex standards in the same order are (124-139), (6.3-10.6) and (86-107) [25]. The effect of cooking oil type, frying

temperature and frying cycle showed that the iodine values ranged from 46.26 to 80.10 as shown in Table 2. The ANOVA from Table 4 suggests that the interaction between the frying temperature and the frying cycle significantly affects the iodine values of samples in this study. In addition, coconut oil has the highest iodine contents regardless of the frying condition. This could be because increased iodine level is directly linked with unsaturation [28]. From the descriptive analysis, an increase in temperature and frying cycle also increases the iodine value of the oils (Table 2). This observation opposes the works of Babu [29] and Omara *et al.* [30] who attributed the reduction in iodine values during oil frying to thermal degradation and oxidation.

3.4. Colour

Colour is an indicator to estimate the degree of deterioration and used oil quality [31]. The used oil for the bitter yam chips production, when physically observed had some colour attributes. The degradation caused by triglycerides oxidation and other chemical reactions between the oil and the product might have led to the oil darkening [32]. Other interactions between the oil, ingredients and food nutrients could contribute to used-oil darkening. The yellowness could relate to the presence of unsaturated carbonyl compounds dissolved in food parts in the oil [31].

3.4.1. L^* (whiteness) Colour Index

Table 4 suggests that the frying cycle, oil type, and the interaction between the frying temperature and frying cycle, significantly affect the L^* (whiteness) value. Peanut oil showed the highest amount of colour index regardless of the frying condition. This could result from thermal degradation during processing in contrast to the other oils that could be cold-pressed.

Observation from Figure 2 shows that the whiteness index of the bitter yam fries decreased with the temperature increase. A gradual decrement in the whiteness colour index was recorded as the frying cycle increased. The increase in temperature and frying cycle also decreases the whiteness of the oils. This observation agreed with Sunisa *et al.* [33].

Factor Coding: Actual

L^*
Design Points:
● Above Surface
○ Below Surface
11.205 25.385

$X1 = B$
 $X2 = C$

Actual Factor
 $A = 1$

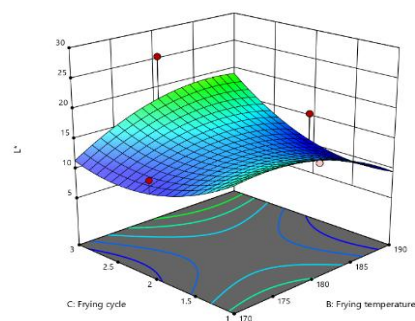


Fig 2. L^* (whiteness) surface plot of the effect of the frying cycle against frying temperature

3.4.2. a^* (redness) Colour Index

Table 4 shows that the quadratic effect of the cooking oil type and frying cycle, and the interaction of the frying cycle and the oil type significantly affect a^* (redness) value. Table 2 shows that soybean oil has the highest amount of redness colour index regardless of the frying condition.

Figure 3 shows no significant changes in the redness colour index of the oil below the 2nd frying cycle. A gradual increment was recorded above the second frying cycle and there was no significant change below 180°C. This could result from the optimal frying temperature for tubers (180°C). In addition, a gradual increment was recorded above this temperature. The interaction between increased temperature and frying cycle above 180°C at the second frying cycle also resulted in an increased redness colour index. This result is similar to the findings of Manzoor *et al.* [31].

Factor Coding: Actual

a^*
Design Points:
● Above Surface
○ Below Surface
-8.27 -4.395

$X1 = B$
 $X2 = C$

Actual Factor
 $A = 1$

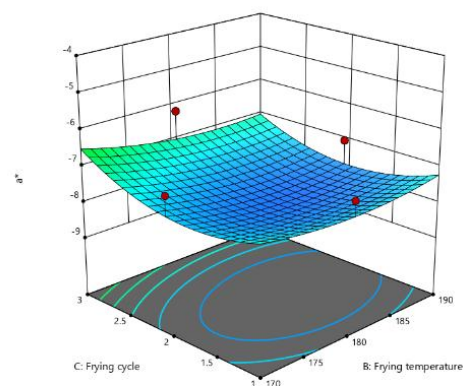


Fig 3. a^* (redness) colour index surface plot of the effect of the frying cycle against frying temperature

3.4.3. b^* (yellowness) Colour Index

The frying cycle significantly affects the b^* (yellowness) values as observed in Table 4. The highest amount of

yellowness colour index was observed in soybean oil regardless of the frying condition. Figure 4 shows the interaction between frying temperature and oil type. The Figure shows no significant changes in the yellowness index below 180°C. However, a gradual increase was recorded above this temperature. This study agrees with the findings of Sunisa *et al.* [33] and Arab *et al.* [34].

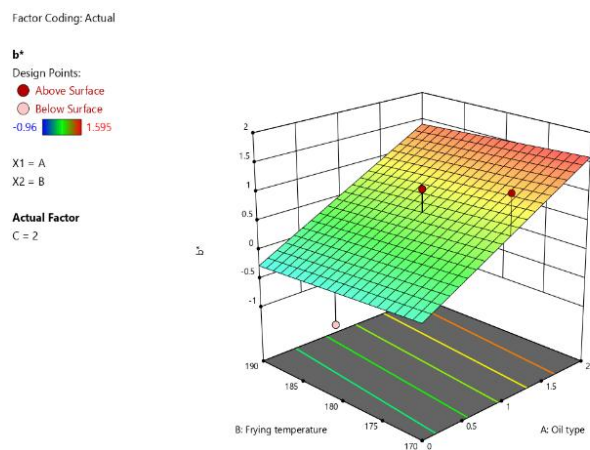


Fig 4. b^* (yellowness) colour index surface plot of the effect of cooking oil type against frying temperature

3.5. Free Fatty Acid

Free fatty acid (FFA) is an undesirable quality of cooking oil and an increase in FFA indicates oil degradation [35]. Table 4 shows that the frying cycle, the interaction of the frying cycle and temperature significantly affect FFA contents (at $p \leq 0.05$). From the result, soybean oil has the highest amount of FFA content regardless of the frying condition. This high FFA has the possibility of increasing the oxidation rate of the oil and supporting quick degradation as the frying cycle increases [27][6]. FFA increases, as the temperature increases (Table 2). The increase in temperature and frying cycle also increases the FFA in the oil. This observation relates to the previous research done by Nayak *et al.* [6].

3.6. p-Anisidine Value

The high value of p-anisidine indicates a high level of hydrolysis, which in turn means a high level of rancidity [6]. Table 4 shows that the frying cycle, oil type and the relation between the frying cycle and frying temperature significantly affect p-anisidine. In this study, peanut oil has the highest amount of p-anisidine value. From Table 3,

there is an increase in the p-anisidine present in the oils as the frying cycle and the interaction between temperatures and the frying cycle increase. This agrees with the findings of Arab *et al.* [34] and Sunisa *et al.* [33].

3.7. Refractive Index

The refractive Index technique helps in evaluating fats and edible oils' rancidity. An increase in the refractive index indicates a rancidity increment [36]. The oil reuse significantly affects the refractive index (Table 4). According to [25] regulations, the acceptable range for refractive indexes of soybean, coconut and peanut oils respectively are (1.466-1.470), (1.448-1.450) and (1.460-1.465). Peanut oil from the results has the highest amount of refractive index regardless of the frying condition and refractive indexes of both soybean and coconut oil change at the same rate.

Table 3 shows an increase in the refractive indexes of the oils as the frying cycle increases. The increase in frying temperature and frying cycle also increased the refractive indexes of the oils. This is in line with [29][36] and [37].

3.8. Saponification Value

The saponification value in oil makes it easy to evaluate the extent of hydrolysis [6]. High SV is a desirable trait in cooking oil due to the delay in the onset of hydrolysis [6]. This study's results show that coconut oil has the highest amount of SV (203.21) at 170°C frying temperature in the 1st frying cycle. The quadratic effect of the frying cycle was observed to significantly affect the saponification value (Table 4).

From Table 3, there is a decrease in SV of the oils as the frying cycle and frying temperatures are increased. Increased temperature and frying cycle decrease the SV of the oils in this study. This result is similar to research by Babu [29] and Abbas [37].

4. Study Limitations

There is limited literature on the influence of frying temperature, frying cycle and cooking oil type on bitter yams during this study. Also, this study used manual means (the use of a hand fork) for detecting if the bitter yams were properly cooked due to the level of funding and local materials available for automated cooking detection. However, adequate safety and hygienic rules were strictly adhered to during the study.

Table 2: Descriptive table showing the effects of frying temperature, cooking oil type and frying cycle on viscosity, iodine, peroxide and colour (L^* , a^* and b^*)

COT	FC	FT	Viscosity	Iodine	Peroxide	L^*	a^*	b^*
CO	1	170	76.85±0.00 ^c	46.23±0.03 ^o	2.17±0.00 ^l	20.07±0.16 ^b	-6.77±0.01 ^c	-0.92±0.69 ^e
SO	1	170	72.34±0.00 ^{bf}	60.05±0.00 ^g	2.03±0.00 ^m	25.09±0.01 ^a	-5.57±0.28 ^b	1.39±0.00 ^a
CO	1	190	0.90±0.00 ^l	80.10±0.00 ^a	3.23±0.02 ^a	17.62±0.09 ^d	-6.25±0.28 ^{bc}	0.29±0.01 ^{bc}
SO	1	190	0.90±0.00 ^l	68.20±0.00 ^f	2.65±0.00 ^e	12.30±0.21 ^f	-6.19±0.07 ^{bc}	1.33±0.06 ^a
CO	3	170	0.90±0.00 ^m	78.20±0.00 ^b	3.05±0.00 ^d	18.44±0.28 ^c	-6.74±0.70 ^c	0.40±0.02 ^{bc}
SO	3	170	74.25±0.00 ^d	68.50±0.00 ^e	2.51±0.01 ^f	12.59±0.22 ^f	-4.40±0.18 ^a	0.80±0.10 ^{ab}
CO	3	190	78.74±0.00 ^a	48.77±0.03 ^m	2.32±0.01 ^h	19.89±0.02 ^b	-7.05±0.38 ^c	-0.96±0.01 ^e
SO	3	190	74.25±0.00 ^d	55.16±0.02 ^l	2.01±0.01 ⁿ	25.23±0.13 ^a	-5.18±0.29 ^{ab}	1.60±0.28 ^a
CO	2	180	78.15±0.00 ^b	46.26±0.01 ⁿ	2.21±0.01 ⁱ	19.90±0.00 ^b	-7.07±0.40 ^c	-0.73±0.32 ^{de}
SO	2	180	72.85±0.00 ^{ae}	58.66±0.01 ^h	2.45±0.00 ^g	25.12±0.02 ^a	-5.17±0.28 ^{ab}	1.40±0.01 ^a
PO	2	170	0.98±0.00 ^j	70.20±0.00 ^d	3.06±0.01 ^c	12.66±0.30 ^f	-6.93±0.11 ^c	1.44±0.15 ^a
PO	2	190	70.34±0.00 ^f	53.48±0.04 ^k	2.14±0.01 ^k	15.45±0.21 ^e	-7.06±0.50 ^c	-0.05±0.07 ^{de}
PO	1	180	69.35±0.00 ⁱ	52.63±0.02 ^l	2.13±0.00 ^l	15.45±0.21 ^e	-7.06±0.50 ^c	-0.05±0.07 ^{de}
PO	3	180	70.26±0.00 ^h	55.21±0.01 ⁱ	2.16±0.01 ^k	25.39±0.64 ^a	-6.21±1.70 ^{bc}	0.93±1.38 ^{ab}
PO	2	180	0.97±0.00 ^k	70.40±0.00 ^c	3.15±0.00 ^b	11.21±0.47 ^g	-8.27±0.85 ^d	1.06±0.14 ^{ab}
PO	2	180	0.97±0.00 ^k	70.40±0.00 ^c	3.15±0.00 ^b	11.21±0.47 ^g	-8.27±0.85 ^d	1.06±0.14 ^{ab}
PO	2	180	0.97±0.00 ^k	70.40±0.00 ^c	3.15±0.00 ^b	11.21±0.47 ^g	-8.27±0.85 ^d	1.06±0.14 ^{ab}
PO	2	180	0.97±0.00 ^k	70.40±0.00 ^c	3.15±0.00 ^b	11.21±0.47 ^g	-8.27±0.85 ^d	1.06±0.14 ^{ab}
PO	2	180	0.97±0.00 ^k	70.40±0.00 ^c	3.15±0.00 ^b	11.21±0.47 ^g	-8.27±0.85 ^d	1.06±0.14 ^{ab}

Where COT is the cooking oil type, FC is the frying cycle, FT is the frying time, CO is the coconut oil, SO is the soybean oil and PO is the peanut oil.

Table 3: Descriptive table showing the effects of frying temperature, oil type and frying cycle on SV, p-Anisidine values (PAV), RI and FFA values

COT	FC	FT	FFA	SV	RI	PA
CO	1	170	0.35±0.26 ^{gh}	203.21±0.99 ^a	1.48±0.00 ^d	2.72±0.00 ^f
SO	1	170	0.21±0.00 ^k	178.43±0.26 ^f	1.46±0.00 ^f	2.41±0.00 ⁱ
CO	1	190	47.27±0.11 ^f	0.35±0.01 ^h	1.48±0.01 ^c	2.59±0.0 ^g
SO	1	190	58.92±0.02 ^b	0.21±0.00 ^h	1.48±0.00 ^c	2.85±0.01 ^e
CO	3	170	49.60±0.08 ^e	0.29±0.00 ^h	1.47±0.00 ^e	2.40±0.00 ⁱ
SO	3	170	62.16±0.04 ^a	0.25±0.00 ^h	1.48±0.00 ^c	2.06±0.06 ^j
CO	3	190	0.35±0.00 ^{gh}	194.46±0.12 ^c	1.50±0.00 ^b	3.05±0.00 ^d
SO	3	190	0.33±0.00 ^h	177.42±0.19 ^g	1.46±0.00 ^f	2.52±0.00 ^h
CO	2	180	0.39±0.00 ^g	200.45±0.00 ^b	1.48±0.00 ^c	2.75±0.00 ^f
SO	2	180	0.27±0.01 ⁱ	177.22±0.19 ^g	1.46±0.00 ^f	2.52±0.00 ^h
PO	2	170	54.07±0.04 ^c	0.31±0.01 ^h	1.52±0.00 ^a	3.22±0.01 ^c
PO	2	190	0.26±0.00 ^{ij}	186.49±0.62 ^d	1.43±0.00 ^g	3.44±0.02 ^a
PO	1	180	0.28±0.00 ⁱ	186.42±0.59 ^d	1.43±0.00 ^g	3.21±0.01 ^c
PO	3	180	0.22±0.00 ^{jk}	184.26±0.12 ^e	1.46±0.00 ^f	3.36±0.02 ^b
PO	2	180	52.16±0.0 ^d	0.36±0.00 ^h	1.52±0.00 ^a	3.41±0.01 ^a
PO	2	180	52.16±0.0 ^d	0.36±0.00 ^h	1.52±0.00 ^a	3.41±0.01 ^a
PO	2	180	52.16±0.01 ^d	0.36±0.00 ^h	1.52±0.00 ^a	3.41±0.01 ^a
PO	2	180	52.16±0.01 ^d	0.36±0.00 ^h	1.52±0.00 ^a	3.41±0.01 ^a
PO	2	180	52.16±0.01 ^d	0.36±0.00 ^h	1.52±0.00 ^a	3.41±0.01 ^a

Table 4: Analysis of variance (ANOVA) for the physiochemical composition of the used cooking oil

Parameters	VS	PV	IV	L^*	a^*	b^*	FFA	PA	RI	SV
p-values										
COT	0.70	0.43	0.36	0.48	0.64	0.88	0.73	0.13	0.63	0.63
FT	0.21	0.69	0.27	0.12	0.37	0.86	0.85	0.51	0.95	0.95
FC	0.00	0.01	0.00	0.00	0.90	0.05	0.00	0.00	0.32	0.32
COT*COT	0.05	0.27	0.16	0.00	0.00	0.21	0.11	0.00	0.72	0.72
FT*FT	0.15	0.64	0.20	0.09	0.36	0.84	0.14	0.47	0.96	0.96
FC*FC	0.13	0.03	0.31	0.04	0.03	0.41	0.11	0.08	0.02	0.02
COT*FT	1.00	0.33	0.55	0.91	0.21	0.45	0.99	0.04	0.66	0.66
COT*FC	1.00	0.88	0.75	0.98	0.03	0.74	0.98	0.00	0.79	0.79
FT*FC	0.00	0.03	0.00	0.00	0.44	0.15	0.00	0.00	0.93	0.93

Cooking oil type (COT), frying temperature (FT), frying cycle (FC), Viscosity (VS), peroxide values (PV), iodine values (IV), whiteness colour index (L^), redness colour index (a^*), yellow colour index (b^*), free fatty acid (FFA), p-anisidine values (PA), refractive index (RI), saponification values (SV)

5. Conclusions

The frying temperature, frying cycle and cooking oil type (peanut, soybean and coconut oils) affected the viscosity, peroxide value, colour (L^* , a^* and b^*), iodine value, FFA, p-anisidine, saponification value and refractive index of the cooking oil used in the production of bitter yam chips. The quadratic effect of cooking oil type affected the a^* while the quadratic effect of the frying cycle influenced the refractive index of the used cooking oil. The used coconut oil had the highest viscosity (78.74), peroxide value (3.23), iodine value (80.10) and saponification value (203.21). However, the used peanut oil had the highest L^* (25.39), p-anisidine (3.44), and refractive index (1.52) while soybean oil had the highest a^* (-4.40), b^* (1.60) and FFA (62.16) at varied frying conditions. This information would be valuable to producers of bitter yam chips on cooking oil reusability and in the selection of appropriate cooking oil

types based on physicochemical composition desirability.

6. Recommendations

Further studies should be done on the influence of the cooking oil types (peanut, soybean and coconut oils) on the nutritional composition of the bitter yam chips. Studies of the bitter yam chips under storage conditions should also be conducted.

Declaration of Competing Interest

The authors report no declarations of interest.

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