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Original Article

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

Musliu Olushola Sunmonu [a], Mayowa Saheed Sanusi[a], Taofeekat Olabowale Jimoh[a], Aishat Olamide Olukokun[a], Aliu Olamide Oyedun[bc,]*

[a]*Department of Food Engineering, University of Ilorin, Ilorin, Nigeria.*
[b]*Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria.*
[c]*Environmental Engineering, Hamburg University of Technology, Hamburg, Germany.*

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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℃, 180℃, 190℃), 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

* *Corresponding author.*
E-mail address: *: aliu.oyedun@tuhh.de*
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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 460ºF (210℃) 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].

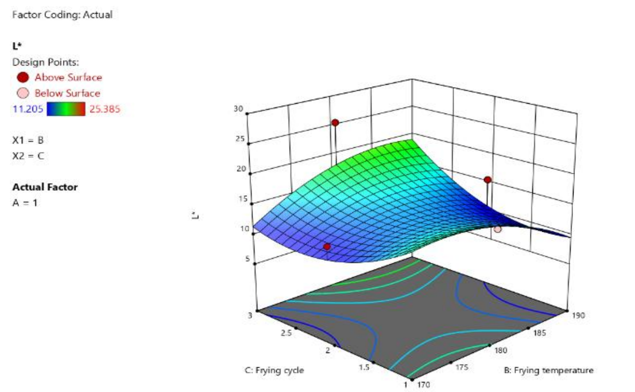

Fig 2. *L**(whiteness) surface plot of the effect of the frying cycle against frying temperature

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].

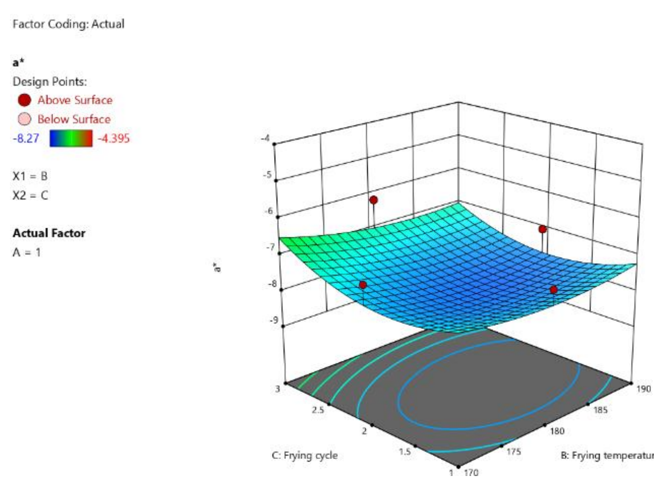

Fig 3. *A**(redness) colour index surface plot of the effect of the frying cycle against frying temperature

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].

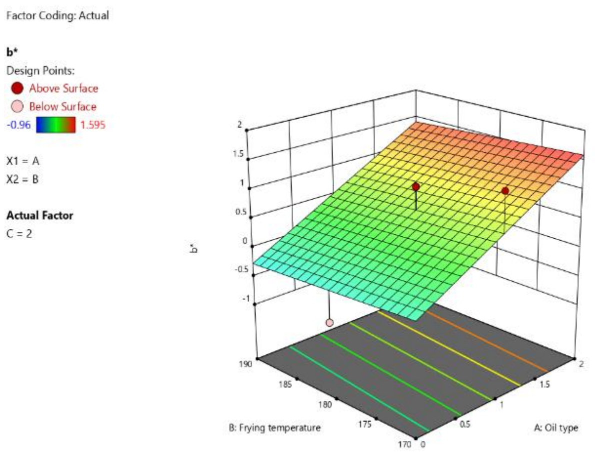

Fig 4. *b**(yellowness) colour index surface plot of the effect of cooking oil type against frying temperature

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 170ºC frying temperature in the 1st frying cycle. The quadratic effect the 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^{j}	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^{j}	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}
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	58.920.02^{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*COT	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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References

1. Lima KCM, Freitas HD, Passos TS, Maciel BLL. The effect of using different oils and paper towel in vegetable oil absorption of fried recipes. *Journal of Culinary Science and Technology*, 2018; 17:1-12. https://doi.org/10.15428052.2018.1465503
2. Borela VL, de Alencar ER, Mendonça MA., Han H, Raposo, A, Ariza-Montes A, Araya-Castillo L, Zandonadi R. Influence of Different Cooking Methods on Fillet Steak Physicochemical Characteristics. *Int. J. Environ. Res. Public Health*, 2022; 19, 606. https://doi.org/10.3390/ijerph19010606
3. Sibai H, Alrifaie H. The Effect of Frying Conditions on Sunflower Oil Attributes. *Tikrit Journal of Engineering on Sciences*, 2018; 25**(**2):52-58.
4. Guillaume C, De Alzaa F, Ravetti L. "Evaluation of Chemical and Physical Changes in Different Commercial Oils during Heating". *Acta Scientific Nutritional Health;* 2018; 2(6):02-11.
5. Li X., Nian B.B., Tan C.P., Liua Y.F., Xu Y.J. 2021. Deep-frying oil induces cytotoxicity, inflammation and apoptosis on intestinal epithelial cells. *J. Sci. Food Agric.*, 2022; 102: 3160–3168, https://doi.org/10.1002/jsfa.11659
6. Nayak P, Dash U, Rayaguru K, Kesavan R. Physio-chemical Changes during Repeated Frying of Cooked Oil. *Journal of Food Biochemistry*, 2015; 40(3):371-390
7. Josephine C, Thomas K, Peter KC. Impact of Frying on Iodine Value of Vegetable oils before and after deep frying in different types of food in Kenya. *Journal of Scientific and Innovative Research*, 2016; 5(5):193-196.
8. Jurić S, Jurić M, Siddiquec Md AB, Fathi M. Vegetable Oils Rich in Polyunsaturated Fatty Acids: Nanoencapsulation Methods and Stability Enhancement. *Food Reviews International*, 2020; 38, 32-69
9. Qin P, Wang T, Luo Y. 2022. A review on plant-based proteins from soybean: Health benefits and soy product development. Journal of Agriculture and Food Research, 2022;1-8. https://doi.org/10.1016/j.jafr.2021.100265
10. Dauber C, Carreras T, Daniel GC, Cabrera F, Liscano A, Vicente G, Britos A, Carro S, Cajarville C, Gámbaro A, Vieitez I. 2022. Adding sunflower or soybean oil to goat’s pasturebased diet improves the lipid profile without changing the sensory characteristics of milk. Journal of Applied Animal Research, 2022;50(1):204-212
11. Fanalli SL, Martins da Silva BP, Gomes JD, Ciconello FN, de Almeida VV, Freitas FAO, Moreira GCM, Vignato BS, Afonso J, Reecy J, Koltes J, Koltes D, Regitano LCA, Baileiro JCC, Freitas L, Coutinho LL, Fukumasu H, de Alencar SM, Filho AL, Cesar ASM. Effect of dietary soybean oil inclusion on liver-related transcription factors in a pig model for metabolic diseases. Scientific Reports, 2022;12, 10318. https://doi.org/10.1038/s41598-022-14069-1
12. Zahran HZ, Tawfeuk HA. Physicochemical properties of new peanut (Arachis hypogaea L.) varieties. *Oilseeds & fats Crops and Lipids (OCL*), 2019; 26:19. https://doi.org/10.1051/ocl/2019018
13. Wongpattananukul S, Nungarlee U, Ruangprach A, Sulong S, Sanporkha P, Adisakwattana S, Ngamukote S. Effect of Inca peanut oil on omega-3 polyunsaturated fatty acids, physicochemical, texture and sensory properties in chicken sausage. LWT - Food Science and Technology, 2022; 163,113559
14. Zhang D, Guo X, Wang Q, Zhao L, Sun Q, Duan X, Cao Y, Sun H. Investigation on lipid profile of peanut oil and changes during roasting by lipidomic approach. LWT - Food Science and Technology, 2022; 154, 112594. https://doi.org/10.1016/j.lwt.2021.112594
15. Ndife J, Obot D, Abasiekong K. Quality Evaluation of Coconut (Cocos nucifera L) Oils Produced by Different Extraction Methods. *Asian Food Science Journal*, 2019; 8(4):1-10. https://doi.org/10.9734/AFSJ/2019/v8i429995
16. Mohamadi PS, Hivechi A, Bahrami H, Hemmatinegad N, Milan PB. 2022. Antibacterial and biological properties of coconut oil loaded poly (e-caprolactone)/gelatin electrospun membranes. Journal of Industrial Textiles, 2022; 51(1S) 906S–930S

17. Zulkifli Z, Rihayat T, Suryani S, Facraniah F, Habibah U, Audina N, Fauzi T, Nurhanifa N, Zaimahwati Z, Rosalina R. Purification Process of Jelantah Oil using Active Charcoal Kepok's Banana. AIP Conference Proceedings, 2018; 020022. https://doi.org/10.1063/1.5082427
18. Leong X, Ng C, Jaarin K, Mustafa MR. Effects of Repeated heating of cooking oils on Antioxidant Content and Endothelial Function. *Austin Journal of Pharmacology and Therapeutics*, 2015; 3:1068.
19. Fweja LWT. The Effects of Repeated Heating on Thermal Degradation of Cooking Oil and its implication on Human Health. *Journal of the Open University of Tanzania*, 2019; 26(1).
20. Firestone, David and Martin, P.Y. (2000). Oils and Fat. *AOAC Official Methods of Analysis*, 2-69.
21. Martín-Alfonso MA, Rubio-Valle JF, Hinestroza JP, Martín-Alfonso JE. Impact of Vegetable Oil Type on the Rheological and Tribological Behavior of Montmorillonite-Based Oleogels. Gels, 2022; 8, 504 https://doi.org/10.3390/gels8080504
22. Cai Y, Wu J, Wang K, Dong Y, Hu J, Qu J, Tian D, Li J, Fu Q. Thermo- controlled, self- released smart wood tailored by nanotechnology for fast clean- up of highly viscous liquids. SamrtMat, 2022;1-16. https://doi.org/10.1002/smm2.1133
23. Amirova LM, Andrianova KA, Amirova LR. Processing method, properties and application of functionally graded polymer materials based on the mixtures of poorly compatible epoxy resins. *Polymers and Polymer Composites*, 2021; 29(9S): S611-S621. https://doi.org/10.1177/09673911211014763
24. Wu G, Ge JC, Kim MS, Choi NJ. NOx–Smoke Trade-off Characteristics in a Palm Oil Fueled CRDI Diesel Engine under Various Injection Pressures and EGR Rates. Applied Sciences, 2022;12,1069. https://doi.org/10.3390/app12031069
25. National Agency for Food and Drug Administration and Control (NAFDAC). Fats and Oils Regulations, 2019;10-22
26. Godswill AC, Amagwula IO, Victory IS, Gonzaga AI. Effects of Repeated Deep Frying on Refractive Index and Peroxide Value of Selected Vegetable Oils. *International Journal of Advanced Academic Research*, 2018; 4:106-119
27. Deen A, Visvanathan R, Wickramarachchi D, Marikkar N, Nammi S, Jayawardanae BC, Liyanagea R. Chemical composition and health benefits of coconut oil: an overview. *J. Sci. Food Agric.* 2021; 101: 2182–2193. https://doi.org/10.1002/jsfa.10870
28. Youngsung K, Jinyoung C, Taeeun K. Oxidative Stability If Soybean Oil After Frying Under Different Storage Temperature. *Culinary Science and Hospitality Research*, 2018; 24(2):79-86
29. Babu AG. Effect of Deep-frying on Physicochemical Characteristics of Sunflower Oil. *International Journal of Innovative Science and Research Technology*, 2020; 5(2):176-180.
30. Omara T, Kigenyi E, Laker F, Adokorach M, Otim G, Kalukusu R, Musau B, Kagoya S, Victoria NB. Effects of Continuous Deep-fat Frying on the Physicochemical Properties of Assorted Brands of Edible Cooking Oils Sold in Greater Metropolitan Kampala. *Asian Journal of Applied Chemistry Research*, 2019; 3(2):1-13.
31. Manzoor S, Masoodi FA, Rashid R, Dar MM. Effect of apple pomace-based antioxidants on the stability of mustard oil during deep frying of French fries. LWT-Food Science and Technology, 2022; 163,1-12. https://doi.org/10.1016/j.lwt.2022.113576
32. Flakelar CL, Adjonu R, Doran G, Howitt JA, Luckett DJ, Prenzler PD. Phytosterol, Tocopherol and Carotenoid Retention during Commercial Processing of Brassica napus (Canola) Oil. *Process*, 2022;10,580. https://doi.org/10.3390/pr10030580
33. Sunisa W, Worapong U, Sunisa S, Saowaluck J, Saowakon W. Quality changes of chicken frying oil as affected of frying conditions. *International Food Research Journal*, 2011; 18(2):615-620.
34. Arab R, Casal S, Pinho T, Cruz R, Freidja ML, Lorenzo JM, Hano C, Madani K, Makhlouf LB. 2022. Effects of Seed Roasting Temperature on Sesame Oil Fatty Acid Composition, Lignan, Sterol and Tocopherol Contents, Oxidative Stability and Antioxidant Potential for Food Applications. Molecules, Molecules, 2022; 27, 4508. https://doi.org/10.3390/molecules27144508
35. Sharma A, Bhardwaj A, Khanduja G, Kumar S, Bagchi S, Kaur R, Sharma M, Singla M, Ravinder T, Bhondekar AP, Devi BLAP. *Food Analytical Methods*, 2022; 15:2652–2663. https://doi.org/10.1007/s12161-022-02320-4
36. Awuchi CG, Ikechukwu OA, Igwe SV, Allan IG. Effects of Repeated Deep Frying on Refractive Index and Peroxide Value of Selected Vegetable Oils. *International Journal of Advanced Academic Research*, 2018; 4(4):106 – 119.
37. Abbas RK. Effect of Frying on Physicochemical Properties of Groundnut Oil. *International Journal of Current Research*, 2018; 10(12):75893-75896. https:doi.org/10.24941/ijcr.33290.12.2018.

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