

## Effect of three types of oils and their level of incorporation on sensory quality of sorghum cookies

<sup>1,2</sup>Goubgou, M., <sup>2</sup>Songré-Ouattara, L.T., <sup>2</sup>Bationo, F., <sup>2</sup>Banhoro, O., <sup>1</sup>Traoré, Y. and <sup>1,\*</sup>Savadogo, A.

<sup>1</sup>University Joseph KI-ZERBO, Doctoral School of Sciences and Technology, Laboratory of Applied Biochemistry and Immunology (LABIA), 03 BP 7021 Ouagadougou 03, Burkina Faso,

<sup>2</sup>Research Institute of Applied Sciences and Technology (IRSAT), Department of Food Technology (DTA), 03 BP 7047 Ouagadougou 03, Burkina Faso

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### Abstract

Lipid (oil and fat) is one of the basic and important components used in the production of cookies. It plays several roles in their composition and a judicious choice of this ingredient makes it possible to have cheap, delicious and very nutritious cookies. This study aimed to evaluate the effect of refined cottonseeds oil (RCO), refined palm oil (RPO) and red (or crude) palm oil (CPO) on sorghum (*Sorghum bicolor* var. Gampela) cookies. Oils were incorporated at levels of 16%, 20% and 24%. Cookies quality were evaluated based on quantitative sensory profile, sensory acceptability, preference classification and paired-comparison test. The results of sensory profile tests showed that the sensory descriptors ranged from very low to medium intensity (1.33 to 3.83 on a scale of 5). Both acceptability and classification tests showed that cookies produced with 20% of refined oil (RCO and RPO) and those with 16% of CPO were the most preferred and RCO and RPO with 20% of the oil were appreciated as control cookies produced with 20% of margarine. The colour, texture and fat impression had most influenced the consumers' preferences. RCO, RPO and CPO exhibit the potential to be used as substitutes to margarine to produce sorghum cookies.

## 1. Introduction

Undernutrition remains a major issue in the world, particularly in developing countries, being an underlying cause of 45% of child mortality (Abubakar *et al.*, 2012; WHO, 2020). In developing countries, nutritional deficiencies are still major causes of death and disease, especially among vulnerable and socially disadvantaged people like women and children less than five years of age (WHO, 2020). It is estimated that up to 219 million children are deficient in vitamin A (Mason *et al.*, 2005) and over 1 billion people are susceptible to zinc deficiency in developing countries (Black *et al.*, 2008). Burkina Faso is one of the developing countries showing a high prevalence of undernutrition. In this country, it is estimated that 360,048 children aged 6-59 months will suffer from acute malnutrition during 2020 (Ministère de la santé, 2020).

In Burkina Faso, like other developing countries, different strategies exist including food diversification to tackle this scourge (FAO, 2013; Bailey *et al.*, 2015;

Vidailhet *et al.*, 2017). Some initiatives are undertaken to develop local food varieties using local raw materials including millet and maize couscous, pre-cooked fonio, tô, paste, pancakes, gruel, infant flours and cookies (Broutin *et al.*, 2003; Songre-Ouattara *et al.*, 2016; Hama-Ba *et al.*, 2019).

Cookies are dry foods made from cereal flour, sugar and fat with other minor ingredients such as milk, salt, flavouring agent and eggs (Manley, 2011; Mancebo *et al.*, 2015; Devi and Khatkar, 2016). These are high-energy-density foods with a long shelf life that vary from three months to several years (Mancebo *et al.*, 2015). Oil is known to be one of the crucial cookies' components affecting its shelf life (Manohar *et al.*, 1999; Mancebo *et al.*, 2015). The oil quality including its origin and concentration is so important for young children (Manohar *et al.*, 1999; Moreno *et al.*, 2014). The quality of lipids in cookies processing determines the quality of the final product including the taste, texture, shelf life and cost (Zoulias *et al.*, 2002; Jacob and Leelavathi, 2007; Devi and Khatkar, 2016).

\*Corresponding author.

Email: [alysavadogo@gmail.com](mailto:alysavadogo@gmail.com)

In Burkina Faso, various oilseeds are used in lipids processing, including cottonseeds, peanuts, shea nuts, sesame seeds, soybeans and cashew nuts (FEWS, 2017; Sawadogo *et al.*, 2020). Indeed, cottonseeds oil is the main vegetable oil produced and the most available. The annual production, in Burkina Faso, was estimated to 125 000 t (Ouédraogo, 2014; Sourabié *et al.*, 2019). In Africa, Burkina Faso with Mali is the first cotton-producing countries. This makes cottonseeds oil a stable and available source of vegetable oil (FEWS, 2017; Sourabié *et al.*, 2019). Alongside cottonseed oils, other oilseeds include palm oil (refined palm oil and red palm oil) largely used in Burkina Faso. Red palm oil was promoted as a source of vitamin A for women and children in central-north Burkina Faso (Zagré *et al.*, 2002). Among children, the risk of inadequate vitamin A intake dropped from 87 to 60%, based on dietary intakes of vitamin A-rich foods, and the prevalence of low serum retinol concentrations ( $\leq 0.70 \mu\text{mol/L}$ ) decreased from 84.5 to 66.9% (Zagré *et al.*, 2002). Also, palm oil is the most widely used vegetable oil in the world because of its competitive price, naturally excellent oxidative stability, unique solid content profile, high nutritional value, free of trans fatty acids and cholesterol, antioxidant properties (May 2013; Noor-Lida *et al.*, 2017). Although there are various oils in Burkina Faso including palm oil and cottonseed oil, margarine remains the most commonly used oil in the production of cookies (Songre-Ouattara *et al.*, 2016; Songre-Ouattara *et al.*, 2017). The use of this lipid is associated with its properties adapted for cookies production such as good texture, plasticity, high melting point and oxidation stability (Tarancón *et al.*, 2013; Louiza and Hafsa, 2017; Costa *et al.*, 2019). However, margarine is imported into most parts of Africa including Burkina Faso and is consequently not always accessible to the general population (FEWS, 2017; Sourabié *et al.*, 2019). In addition, some components of margarine including trans fatty acids can be an underlying cause of human health disorders (Dhaka *et al.*, 2011; Costa *et al.*, 2016; Louiza and Hafsa, 2017; Costa *et al.*, 2019). Due to the characteristics of industrial trans fats (texture, plasticity and high melting point) (Tarancón *et al.*, 2013; Costa *et al.*, 2016), it is a challenge to develop cookies using other lipid sources (Costa *et al.*, 2019).

In line with dietary diversification to promote the consumption of nutrient-rich foods, there is a need to investigate other processing cookies using local raw material (Yeh *et al.*, 1998). However, the production of cookie with cottonseeds oil and palm oil, as the oil used locally, might impact the sensory quality of products, such as colour, odour, aroma, texture, flavour, fat impression, bitter aftertaste and overall acceptability.

This study aimed to evaluate the effect of RCO, RPO and CPO on the sensory properties of sorghum cookies. RCO, RPO and CPO were selected because of their availability, acceptability, inexpensive cost and their essential fatty acids and carotenoid content. These fats could thus replace margarine in the production of cookies.

## 2. Materials and methods

### 2.1 Raw materials used in the production of cookies

Sorghum (*Sorghum bicolor* Var. Gampela) grains were purchased in Ouagadougou (Burkina Faso) and processed into flour after shelling and milling at the Food Technology Department (DTA) of the Research Institute for Applied Sciences and Technologies (IRSAT) in Ouagadougou. RCO, RPO, CPO, margarine, sugar, powdered milk, eggs, salt, vanilla sugar, baking powder and maize starch were purchased from a food trade in Ouagadougou.

### 2.2 Process of cookies production

The cookies were produced by adapting the process developed by Songré-Ouattara *et al.* (2017) (Figure 1). Only, the fat and flour contents varied, but the total percentage was kept constant to 72.9% for each cookie (Table 1). For each type of fat, three levels of incorporation were used: 16%, 20% and 24%, resulting in 9 cookie formulas. A control cookie was produced with margarine at the level of 20%. The cookies formula codification was given in Table 2.

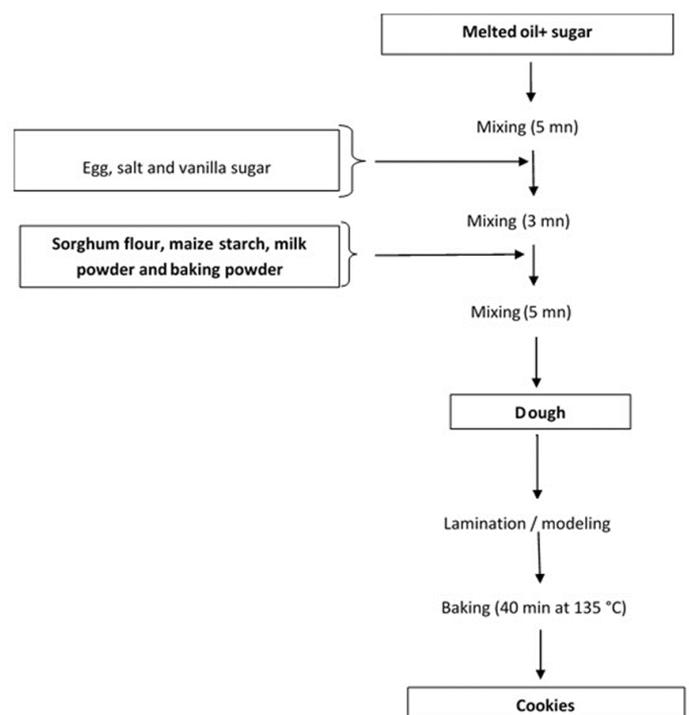


Figure 1. Cookie production adapted from Songré-Ouattara *et al.* (2017)

Table 1. Composition and formulation of the cookies

Ingredients	Proportion of ingredients (%)		
	F1	F2	F3
Flour	56.9	52.9	48.9
Fat	16	20	24
Powder sugar	11	11	11
Egg	7.3	7.3	7.3
Maize starch	4	4	4
Milk powder	1.7	1.7	1.7
Baking powder	1.7	1.7	1.7
Vanilla sugar	1.3	1.3	1.3
Salt powder	0.1	0.1	0.1

F1: Formula 1, F2: Formula 2, F3: Formula 3

Table 2. Type of cookies produced and their codes

Type of cookies	Formula		
	F1	F2	F3
Cookies produced with refined cottonseed oil	RCO16	RCO20	RCO24
Cookies produced with refined palm oil	RPO16	RPO20	RPO24
Cookies produced with red palm oil	CPO16	CPO20	CPO24
Control cookies produced with margarine		M20	

The cookies were produced at the workshop of the Food Technology Department (DTA) of the Research Institute for Applied Sciences and Technologies (IRSAT) in Ouagadougou. After production, the cookies were packaged in a plastic bag and hermetically sealed using a thermo-sealing machine. They were then stored at room temperature (around 28°C) and protected from light for further analysis.

Table 3. Definition of descriptors used to assess the sensory profile of the cookies produced

Descriptor	Definition	Scale of appreciation (1-5)	
<b>Colour</b>			
brown	The intensity of brown colour perceived by tasters	1 = Very low intensity, 2 = Low intensity, 3 = Medium intensity, 4 = High intensity and 5 = Very high intensity	
yellow	The intensity of yellow colour perceived by tasters		
<b>Odour</b>			
caramel	The intensity of nasal sensation of caramel smell perceived by tasters		
vanilla	The intensity of nasal sensation of vanilla smell perceived by tasters		
palm oil	The intensity of nasal sensation of the smell of palm oil perceived by tasters		
<b>Aroma</b>			
caramel	The intensity of retro-nasal sensation of caramel aroma perceived by tasters		
vanilla	The intensity of retro-nasal sensation of vanilla aroma perceived by tasters		
palm oil	The intensity of retro-nasal sensation of Palm oil aroma perceived by tasters		
<b>Texture</b>			
granular	The intensity of granular texture in the mouth perceived by the tasters		
fouder	The intensity of the founding texture in the mouth perceived by tasters		
crunchy	The intensity of the crunchy texture in the mouth perceived by tasters		
<b>Taste</b>			
sweet	The intensity of sweet taste in the mouth perceived by tasters		
salty	The intensity of salty taste in the mouth perceived by tasters		
bitter	The intensity of bittersweet in mouth perceived by tasters		
Fat impression	The intensity of fat in the mouth perceived by tasters		
Bitter aftertaste	The intensity of bitter aftertaste perceived by tasters		

### 2.3 Determination of sensory attributes of cookies

The sensory attribute includes sensory profile, Acceptability test, Ranking test and paired-comparison test. To perform these determinations, a total of 11 panels was done with 48 experienced tasters. During each panel, three or four different cookies were coded and placed on a plate using a random table (Cochran and Cox, 1957).

#### 2.3.1 Sensory profile

The sensory profile of cookies was determined according to the model described by Stone and Sidel (2004). A quantitative assessment of 16 descriptors was made on a 5-point scale ranging from 1 (very low intensity perceived) to 5 (very high intensity perceived). Definitions of all sensory terms are given in Table 3. Thus, each taster was provided with cookies of the same oil at different levels of incorporation, together with water to rinse the mouth after each cookie. The tasters reported their assessments on a data collection sheet.

#### 2.3.2 Acceptability test

The assessment of the acceptability of cookies was determined according to the process described by Meilgaard *et al.* (2007) through the following sensory descriptors: colour, aroma, odour, texture, taste, fat impression, aftertaste and overall acceptability. A hedonic scale from 1 to 5 was used to assess each descriptor (Table 4) (Meilgaard *et al.*, 2007). The three cookies (16%, 20% and 24% of oil) coded in a tasting tray were brought to each taster simultaneously. They

Table 4. Definition of descriptors used to assess the acceptability of cookies produced

Descriptor	Definition	Scale of appreciation
Colour	Colour preference by visual	1 = very mediocre, 2 = mediocre, 3 = neither- mediocre - nor beautiful, 4 = beautiful and 5 = very beautiful
Odour	Odour preference by nasal sensation	1 = very bad, 2 = bad, 3 = neither bad - nor good, 4 = good and 5 = very good
Aroma	Aroma preference by retronasal sensation	
Texture	Texture preference in the mouth	
Taste	Taste preference of cookies in mouth	1 = very unpleasant, 2 = unpleasant, 3 = neither unpleasant - nor pleasant, 4 = pleasant and 5 = very pleasant
Bitter Aftertaste	Taste Preference of cookies in mouth after tasted	
Overall acceptability	Global preference taking into account all descriptors	
Fat impression	Fat sensation preference in the mouth	1 = very fatty, 2 = fatty, 3 = neither fatty - nor dry, 4 = dry and 5 = very dry

were then asked to complete the acceptability sheet.

### 2.3.3 Ranking test

The ranking test made it possible to classify cookies in order of preference according to the method described by Watts *et al.* (1991). Two series of ranking test were performed and the cookies were always ranked from the least pleasant to the most pleasant. For the first series of ranking, the three cookies formula of each oil were presented simultaneously to each taster for ranking. And then, the most pleasant cookies of each oil were selected with the control cookies to proceed for the second-ranking test. These four cookies were presented simultaneously to each taster for ranking.

### 2.3.4 Paired-comparison tests of cookies

The paired-comparison test allowed the comparison of each of the most pleasant cookies of each oil to control cookies following the model described by Stone *et al.* (2012). Then, the four coded cookies were brought to each taster simultaneously. Each taster was then asked to note on a degustation sheet if there were any differences between the most pleasant cookies of each oil and the control cookies M20. A comparison scale of four levels were used, of which: 1 = no difference, 2 = slightly different, 3 = different and 4 = very different.

### 2.4 Statistical analysis of cookies

Data were keying using IBM SPSS Statistics 21 software and descriptive analysis were generated. The sensory profile and acceptability data were statistically treated using a one-way analysis of variance (ANOVA) with the XLSTAT software, version 2016.02.27444. The means were compared by Tukey test at a significance level of 5%. For the acceptability test, the Pearson correlation coefficient was generated with R software using the package GGplot2 (Team, 2016). This made it possible to determine the interactions between the different descriptors studied. The Liker diagram of the overall acceptability of cookies was also generated with the R software. To compare the ranking test results, the Friedman test was used, followed where appropriate, by

rank-sum multiple comparison tests. Finally, the diagrams of spider were made from the results of the ranking and paired-comparison tests with the excel software, version 2016.

## 3. Results

### 3.1 Presentation of cookies

After production, ten samples of cookies were obtained: three cookies for each of the free oil type (16, 20 and 24% of incorporation) and one of control cookie produced with margarine. Figure 2 shows the two faces of the different cookies produced.

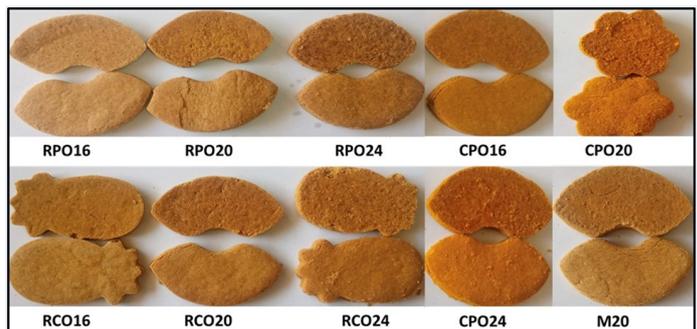


Figure 2. The two faces of the different cookies produced

### 3.2 Sensory profile of cookies produced

The results of the assessment of the intensity of the different descriptors are shown in Table 5. The brown colour was assessed on all cookies, while the yellow colour was assessed on cookies produced with red palm oil (CPO16, CPO20 and CPO24). For the brown colour, the cookies showed three levels of intensity, i.e., very low, low and medium. Cookies produced with 24% of oil (RPO24, RCO24 and CPO24) had consistently the highest brown colour intensities. For cookies produced with refined oils, those with 24% of the oil were significantly different ( $p < 0.05$ ) to those produced with 16 and 20% of oil. For cookies CPO20 and CPO24, the intensities of the brown colour were not significantly different ( $p = 0.073$ ). For the yellow colour, the cookies CPO16 has a higher intensity and differs significantly from cookies CPO20 and CPO24 ( $p < 0.0001$ ).

For caramel odour, the cookies RPO24, RCO24 and

Table 5. Sensory profiles of the cookies produced

		RPO16	RPO20	RPO24	RCO16	RCO20	RCO24	CPO16	CPO20	CPO24
Colour	Brown	3.08 <sup>cd</sup>	2.40 <sup>ab</sup>	3.81 <sup>c</sup>	2.60 <sup>bc</sup>	3.00 <sup>cd</sup>	3.71 <sup>c</sup>	1.94 <sup>a</sup>	3.25 <sup>dc</sup>	3.27 <sup>c</sup>
	Yellow	-	-	-	-	-	-	3.71 <sup>b</sup>	1.94 <sup>a</sup>	2.46 <sup>a</sup>
Odour	Caramel	2.25 <sup>abc</sup>	2.19 <sup>ab</sup>	3.06 <sup>d</sup>	2.23 <sup>ab</sup>	2.56 <sup>abcd</sup>	2.94 <sup>cd</sup>	2.02 <sup>a</sup>	2.75 <sup>bcd</sup>	3.10 <sup>d</sup>
	Vanilla	2.13 <sup>a</sup>	2.48 <sup>a</sup>	2.08 <sup>a</sup>	1.83 <sup>a</sup>	2.38 <sup>a</sup>	2.29 <sup>a</sup>	2.25 <sup>a</sup>	2.31 <sup>a</sup>	2.50 <sup>a</sup>
	Crude palm	-	-	-	-	-	-	2.13 <sup>a</sup>	2.54 <sup>ab</sup>	2.92 <sup>b</sup>
Aroma	Caramel	2.38 <sup>ab</sup>	2.08 <sup>a</sup>	2.69 <sup>ab</sup>	2.33 <sup>ab</sup>	2.65 <sup>ab</sup>	2.85 <sup>b</sup>	2.06 <sup>a</sup>	2.54 <sup>ab</sup>	2.65 <sup>ab</sup>
	Vanilla	2.02 <sup>a</sup>	2.13 <sup>a</sup>	1.96 <sup>a</sup>	2.04 <sup>a</sup>	2.31 <sup>a</sup>	2.35 <sup>a</sup>	2.33 <sup>a</sup>	2.29 <sup>a</sup>	2.44 <sup>a</sup>
	Crude palm	-	-	-	-	-	-	2.08 <sup>a</sup>	2.69 <sup>b</sup>	2.96 <sup>b</sup>
Texture	Granular	3.08 <sup>a</sup>	2.88 <sup>a</sup>	2.96 <sup>a</sup>	2.71 <sup>a</sup>	2.94 <sup>a</sup>	3.06 <sup>a</sup>	2.60 <sup>a</sup>	2.92 <sup>a</sup>	3.02 <sup>a</sup>
	Fondante	2.25 <sup>a</sup>	2.79 <sup>ab</sup>	3.29 <sup>b</sup>	2.42 <sup>a</sup>	2.90 <sup>ab</sup>	3.17 <sup>b</sup>	2.63 <sup>ab</sup>	2.60 <sup>ab</sup>	2.81 <sup>ab</sup>
	Crunchy	3.04 <sup>b</sup>	2.40 <sup>ab</sup>	1.88 <sup>a</sup>	2.54 <sup>ab</sup>	2.38 <sup>ab</sup>	2.21 <sup>a</sup>	2.52 <sup>ab</sup>	2.21 <sup>a</sup>	2.50 <sup>ab</sup>
Taste	Sweet	2.54 <sup>ab</sup>	2.69 <sup>ab</sup>	2.58 <sup>ab</sup>	2.29 <sup>a</sup>	2.79 <sup>ab</sup>	2.96 <sup>b</sup>	2.83 <sup>ab</sup>	2.69 <sup>ab</sup>	2.79 <sup>ab</sup>
	Salt	1.81 <sup>a</sup>	1.69 <sup>a</sup>	2.13 <sup>a</sup>	1.92 <sup>a</sup>	1.92 <sup>a</sup>	1.96 <sup>a</sup>	2.00 <sup>a</sup>	1.96 <sup>a</sup>	2.02 <sup>a</sup>
	Bitter	-	-	-	-	-	-	1.60 <sup>a</sup>	2.04 <sup>a</sup>	1.60 <sup>a</sup>
	Fat impression	2.02 <sup>ab</sup>	2.17 <sup>abc</sup>	2.79 <sup>cd</sup>	1.96 <sup>a</sup>	2.25 <sup>abcd</sup>	2.73 <sup>bcd</sup>	2.08 <sup>abc</sup>	2.69 <sup>abcd</sup>	2.94 <sup>d</sup>
	Bitter aftertaste	1.63 <sup>ab</sup>	1.33 <sup>a</sup>	1.54 <sup>a</sup>	1.58 <sup>ab</sup>	1.42 <sup>a</sup>	1.58 <sup>ab</sup>	1.67 <sup>ab</sup>	2.21 <sup>b</sup>	1.85 <sup>ab</sup>

Values with the same superscript in the same row are not significantly different at  $p < 0.05$ .

16, 20 and 24: incorporation level of each type of oil.

CPO24 had the highest intensities and differed significantly ( $p < 0.05$ ) from cookies RPO16, RCO16 and CPO16 respectively. For vanilla odour, cookies RCO20, RPO20 and CPO24 had the highest intensities. There was no significant difference ( $p > 0.05$ ) in the assessment of the intensity of vanilla odour of all cookies. The red palm odour was assessed only on cookies produced with red palm oil. Cookies CPO24 had the highest intensities of red palm odour and differed significantly from cookies CPO16 ( $p = 0.002$ ).

For caramel aroma, cookies RPO24, RCO24 and CPO24 had the highest intensities in each type of oil cookies. Only cookies RCO24 showed a significant difference from cookies RPO20 and CPO16 ( $p = 0.015$  and  $p = 0.011$  respectively). For vanilla aroma, cookies RPO20, RCO24 and CPO24 had the highest intensities. There was no significant difference ( $p > 0.05$ ) in the assessment of the intensity of the vanilla aroma of cookies. For the red palm aroma, it concerned only cookies produced with red palm fat. Cookie CPO24 had the highest intensity (2.96 on a scale of 5) and are significantly different ( $p = 0,001$ ) from cookie CPO16.

For the granular texture, cookies RPO16, RCO24 and CPO24 showed the highest intensities. The granular texture of cookies did not vary significantly ( $p > 0.05$ ). For the melting texture, cookies RPO24, RCO24 and CPO24 showed the highest intensities. The melting textures of cookies RPO16 and RCO16 were significantly different ( $p < 0.05$ ) from cookies RPO24 and RCO24. No significant difference ( $p > 0.05$ ) was reported in the appreciation of the intensity of melting texture of cookies produced with red palm fat. For crunchy texture, cookies RPO16, RCO16 and CPO16

had the highest intensities. Cookies produced with refined cottonseed oil and red palm fat did not show a significant difference ( $p > 0.05$ ) in the assessment of crunchiness intensity. For cookies produced with refined palm oil, cookies RPO16 showed a significant difference from cookies RPO24 ( $p < 0.0001$ ).

For sweetness, cookies RPO20, RCO16 and CPO16 had the highest intensities for each type of fat. Only cookies RCO16 showed an intensity of sweetness significantly different ( $p = 0.012$ ) from cookies RCO24. For salty taste, cookies RPO24, RCO24 and CPO24 had the highest intensities. No significant difference ( $p > 0.05$ ) was reported for the intensity of the salty taste of cookies. The bitter taste was appreciated on cookies produced with red palm fat. Cookies CPO20 had the highest bitterness intensities. However, no significant difference ( $p > 0.05$ ) was observed in the bitterness intensity of the three cookies. For the fat impression, cookies RPO24, RCO24 and CPO24 showed the highest intensities in each type of oil and significant differences ( $p < 0.05$ ) from cookies RPO16, RCO16 and RPO16 respectively.

For the intensity of the bitter aftertaste, the cookies RCO24, RCO16, RPO16 and CPO20 had the highest intensities. Only cookies CPO24 differ significantly ( $p < 0.05$ ) from cookies RPO20, RPO24 and RCO20.

### 3.3 Acceptability of cookies produced

The results of the acceptability of the various descriptors are shown in Table 6. These results represent the average assessment of forty-eight tasters. The colour of cookies RCO20 and RPO20 were more preferred comparatively to cookies RCO16, RCO24, RPO16 and

Table 6. Acceptability of the cookies produced

	RPO16	RPO20	RPO24	RCO16	RCO20	RCO24	CPO16	CPO20	CPO24
Colour	4.06 <sup>bcd</sup>	4.27 <sup>d</sup>	3.63 <sup>ab</sup>	3.85 <sup>abcd</sup>	4.13 <sup>cd</sup>	3.54 <sup>a</sup>	3.98 <sup>abcd</sup>	3.60 <sup>ab</sup>	3.71 <sup>abc</sup>
Odour	3.73 <sup>ab</sup>	3.81 <sup>ab</sup>	3.54 <sup>a</sup>	3.56 <sup>a</sup>	3.90 <sup>b</sup>	3.52 <sup>a</sup>	3.60 <sup>ab</sup>	3.60 <sup>ab</sup>	3.63 <sup>ab</sup>
Aroma	3.71 <sup>ab</sup>	3.92 <sup>b</sup>	3.54 <sup>ab</sup>	3.48 <sup>a</sup>	3.83 <sup>ab</sup>	3.69 <sup>ab</sup>	3.60 <sup>ab</sup>	3.42 <sup>a</sup>	3.63 <sup>ab</sup>
Texture	3.81 <sup>ab</sup>	4.08 <sup>b</sup>	4.02 <sup>ab</sup>	3.79 <sup>ab</sup>	4.13 <sup>b</sup>	3.90 <sup>ab</sup>	3.79 <sup>ab</sup>	3.56 <sup>a</sup>	3.58 <sup>a</sup>
Flavour	3.96 <sup>bcd</sup>	4.17 <sup>cd</sup>	4.04 <sup>bcd</sup>	3.77 <sup>abc</sup>	4.29 <sup>d</sup>	3.92 <sup>abcd</sup>	3.69 <sup>ab</sup>	3.48 <sup>a</sup>	3.75 <sup>abc</sup>
Fat impression	2.98 <sup>a</sup>	3.19 <sup>ab</sup>	3.77 <sup>c</sup>	3.06 <sup>a</sup>	3.31 <sup>abc</sup>	3.63 <sup>bc</sup>	3.08 <sup>a</sup>	3.46 <sup>abc</sup>	3.73 <sup>c</sup>
Bitter aftertaste	3.73 <sup>abc</sup>	4.04 <sup>c</sup>	3.77 <sup>bc</sup>	3.81 <sup>bc</sup>	4.00 <sup>bc</sup>	3.75 <sup>bc</sup>	3.73 <sup>abc</sup>	3.27 <sup>a</sup>	3.54 <sup>ab</sup>
Overall acceptability	3.85 <sup>bc</sup>	4.15 <sup>c</sup>	2.08 <sup>ab,c</sup>	3.79 <sup>abc</sup>	4.15 <sup>c</sup>	3.83 <sup>bc</sup>	3.81 <sup>abc</sup>	3.40 <sup>a</sup>	3.56 <sup>ab</sup>

Values with the same letter in the same row are not significantly different at  $p < 0.05$

RPO24. However, cookies RPO16 and RCO16 are not significantly different from cookies RPO20 and RCO20 respectively ( $p = 0.080$  and  $p = 0.469$  respectively). For the cookies produced with red palm oil, the colour of cookies CPO16 was over preferred from cookies CPO20 and CPO24. Statistical analysis did not show any significant difference between the assessment of the acceptability of colour of these cookies ( $p > 0.05$ ).

The odours of cookies RCO20, RPO20 and CPO24 were the most liked. For the assessment of the odour of the six cookies produced with palm oil (red and refined), the statistical analysis did not reveal any significant difference ( $p > 0.05$ ). However, the assessment of odour acceptability of cookies RCO20 was significantly different from the odour of cookies RCO16 and RCO24 ( $p = 0.028$  and  $p = 0.013$  respectively).

For the assessment of aroma acceptability, cookies RCO20 and RPO20 were the most preferred than cookies RCO16, RCO24, RPO16 and RPO24. For those produced with red palm oil, cookies OPO24 were most preferred from cookies CPO16 and CPB20. However, for each of these three oils, there was no significant difference in the assessment of the aroma of cookies ( $p > 0.05$ ).

For the assessment of texture acceptability, the cookies RCO20, RPO20 and RPO16 were the most preferred and they differ significantly from the other two cookies for each type of oil ( $p \leq 0.05$ ).

For the assessment of taste acceptability, cookies RCO20, RPO20 and CPO24 were most preferred. Cookies produced with refined palm oil (RPO16, RPO20 and RPO24) and those with red palm oil (RPO16, RPO20 and RPO24) did not show any significant difference in the assessment of their taste acceptability ( $p > 0.05$ ). For cookies produced with refined cottonseed oil, the most preferred cookies RCO20 are significantly different from the acceptability of taste of cookies RCO16 ( $p = 0.012$ ).

For the assessment of the acceptability of fat impression, all cookies were classified as Neither fat -

Nor Dry (Rank 3 on the scale of 5); except cookies RPO16. For each type of oil, tasters reported that cookies RPO24, RCO24 and CPO24 were the fattiest compared to cookies produced with 16 and 20% of oil. Cookies RPO24 differed significantly from cookies RPO16 and RPO20 ( $p < 0.0001$  and  $p = 0.006$  respectively). Cookies RCO16 and CPO16 presented a fat impression significantly different from cookies RPO24, RCO24 and CPO24 ( $p \leq 0.05$ ).

For the acceptability of aftertaste, the cookies RCO20, RPO20 and CPO16 were the most preferred. No significant difference has been reported on the assessment of the aftertaste of cookies produced with each type of oils ( $p > 0.05$ ). However, cookies produced with red palm oil showed an aftertaste significantly different from the majority of cookies produced with refined oils ( $p \leq 0.05$ ).

#### 3.4 Overall assessment of the acceptability of cookies

The results of the overall assessment show that cookies RCO20, RPO20 and CPO16 were the most preferred ones respectively in each type of oil. Only cookies produced with 20 and 24% of red palm oil had overall acceptability significantly different from the other cookies. However, there was no significant difference in the assessment of the acceptability of cookies produced with red palm oil. The *liker-disliker* diagram (Figure 3) was used to group the overall acceptability into three (03) parts. The positive assessment (pleasant and very pleasant) is presented on the right and varied from 45.8% to 93.8%. Negative assessment (Unpleasant and very unpleasant) is presented in the middle and varied from 2.1% to 10.4% of the tasters. On the left are presented the percentages of neutral tasters who find cookies to be neither pleasant - nor unpleasant. These neutral appreciations varied from 4.2 to 43.8% of tasters. However, the number of tasters who found the cookies unpleasant or very unpleasant remains marginal (less than 10.5%). For cookies produced with the two refined oils, at least 64% of the tasters reported that the cookies were pleasant or very pleasant.

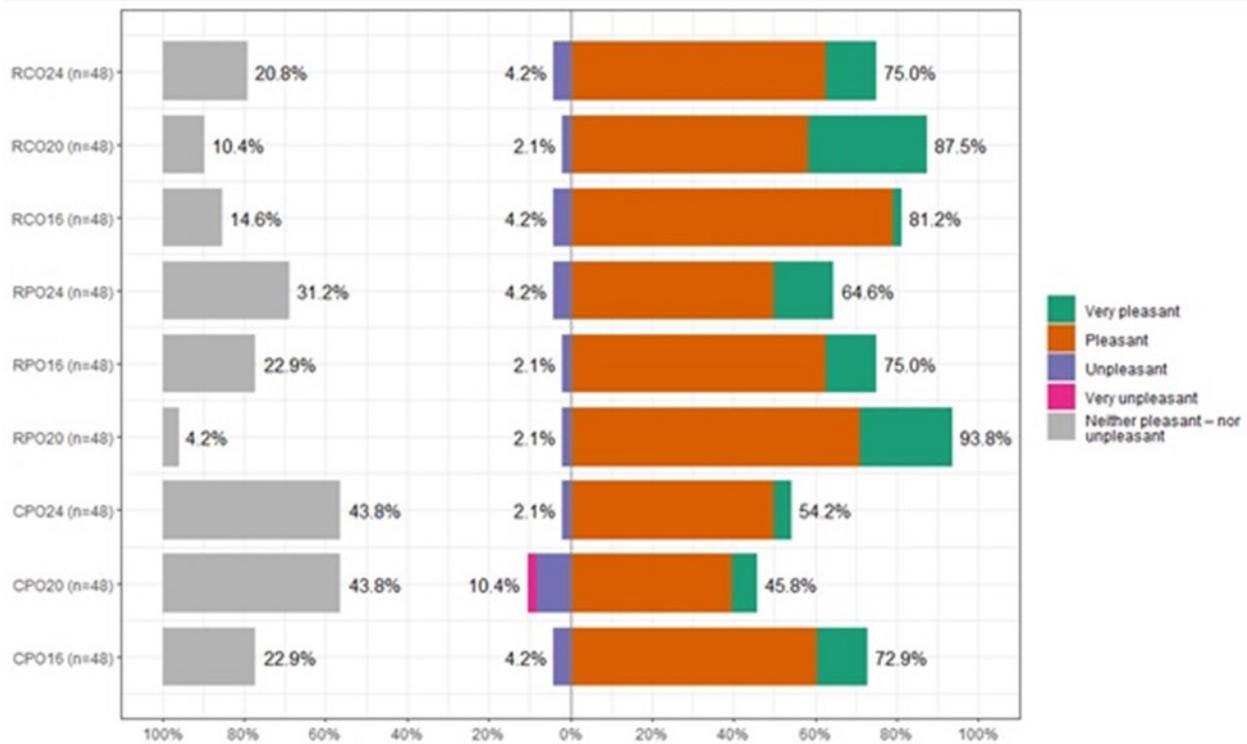


Figure 3. Liker-Disliker diagram of the overall acceptability of biscuits produced

### 3.5 Correlation between the different hedonic descriptors of the cookies produced

Figure 4 shows the correlations between the different hedonic descriptors of the cookies produced. It appears that there is a positive correlation ( $r = 0.08$  to  $0.93$ ) between certain hedonic descriptors such as colour, odour, aroma, flavour, texture, bitter aftertaste and overall acceptability. However, the fat impression of the cookie is negatively correlated ( $r = -0.04$  to  $-0.72$ ) with the other hedonic descriptors. These different correlations are significant at  $p \leq 0.001$  between texture and bitter aftertaste; at  $p \leq 0.01$  between colour and odour, between odour and aroma, between texture and flavour, between flavour and bitter aftertaste; at  $p \leq 0.05$  between colour and aroma, between colour and bitter aftertaste, between colour and overall acceptability, between odour and flavour, between aroma and texture, between aroma and flavour and between aroma and bitter aftertaste.

### 3.6 Ranking and paired-comparison tests of cookies

The Spider diagrams below show the results of the ranking by preference test and those of paired-comparison test of cookies (Figure 5). The cookies RCO20, RPO20 and CPO16 are the top in the classification (Figures 5 A, B and C) of cookies with each oil and are therefore the most preferred. For the classification with control cookies (M20), cookies RCO20 came first in the ranking. Figure 5 A, B and C show the best incorporation level of each type of oil according to the first three ranking tests. For the two refined oils (cottonseeds and palm), cookies RCO20 and RPO20 were ranked first and are significantly different

to the cookies prepared with 16% of oil ( $p \leq 0.05$ ) (Table 7). Figures 5A and B show that cookies RCO20 and RPO20 tend towards the same classification, namely the top position. The classification of the free best appreciates cookies (RCO20, RPO20 and CPO16) with the control cookie M20 (Table 7) showed no significant difference between cookies RCO20 and RPO20 to the cookies M20. However, cookies RPO16 significantly different to the control cookies and the cookies RCO20 and RPO20. For the three types of cookies produced with crude palm oil, cookies CPO16 were ranked first (Figure

Table 7. Result of ranking test of cookies produced

Type of cookies	Rank
Refined palm oil cookies	
RPO16	2 <sup>a</sup>
RPO20	1 <sup>b</sup>
RPO24	3 <sup>ab</sup>
Refined cottonseeds oil cookies	
RCO16	3 <sup>a</sup>
RCO20	1 <sup>b</sup>
RCO24	2 <sup>ab</sup>
Red palm oil cookies	
CPO16	1 <sup>a</sup>
CPO20	3 <sup>b</sup>
CPO24	2 <sup>ab</sup>
Comparison to control cookies M20	
M20	2 <sup>a</sup>
RPO20	3 <sup>ac</sup>
RCO20	1 <sup>ac</sup>
CPO16	4 <sup>b</sup>

Values with the same superscript in every group of ranking are not significantly different at  $p < 0.05$

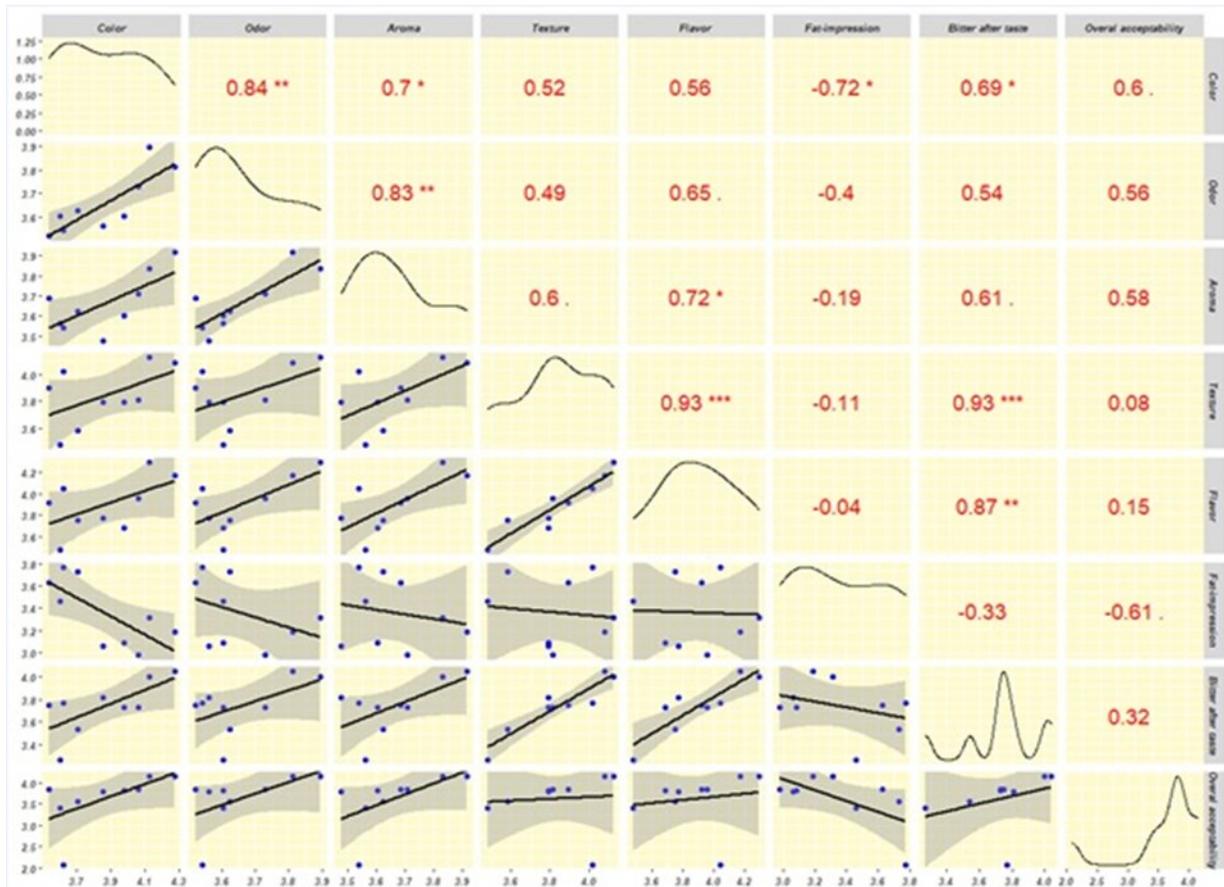


Figure 4. Correlation between the hedonic descriptors of the cookies produced. Statistical significance at  $p \leq 0.05$ ; 0.01 and 0.001, are shown using \*, \*\*, \*\*\* respectively.

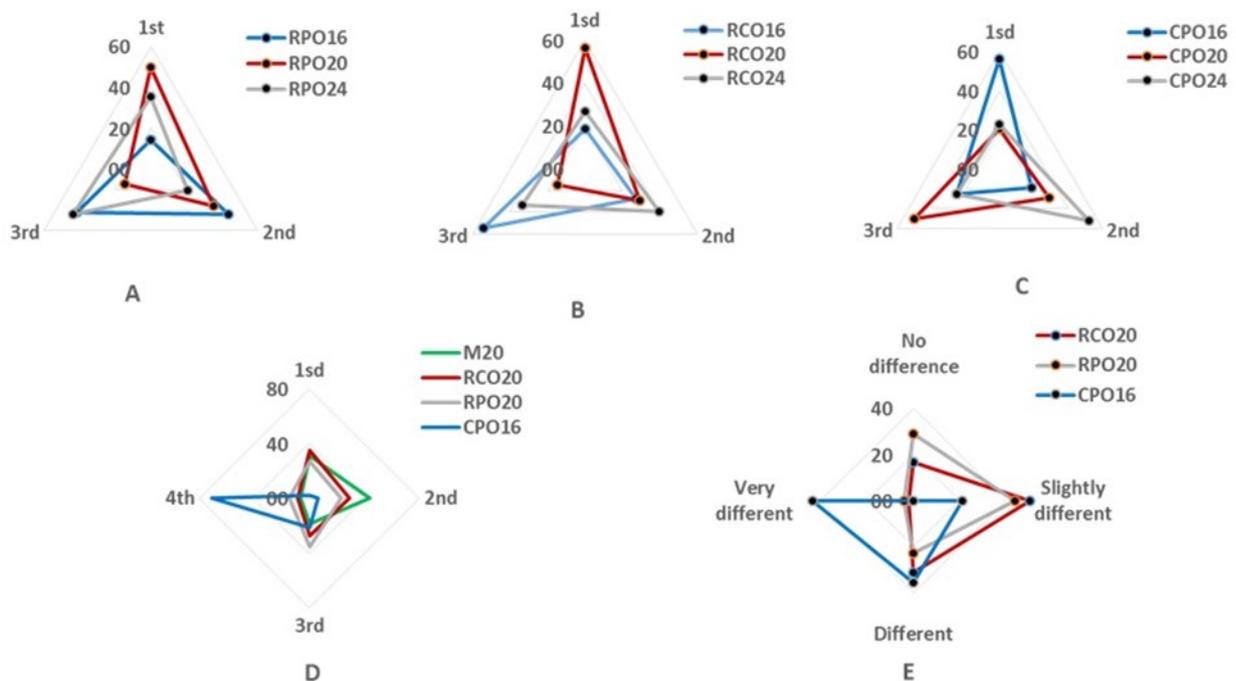


Figure 5. Spider diagram of the tests of ranking (A, B, C and D) and paired-comparison tests (E) of cookies produced (5C). The cookies produced with 20% refined cottonseeds and palm oils and those with 16% red palm oil, having the highest acceptability and ranked first in the various classification tests, were used in comparison tests to control cookies. The results of this classification are shown in Figure 5D and present the classification of the cookies according to the order: RCO20, M20 (control cookie), RPO20 and CPO16 respectively first, second, third and fourth. Figure 4E displays the results of the difference of cookies RPO20, RCO20 and CPO16 to the control cookies M20. Cookies CPO16 are distinguished from control cookies and occupy two vertices: “different” and “very different”. 29.2% of tasters did not find any difference between cookies RPO20 to the control cookies M20. It was 16.7% between the cookies RCO20 to the control cookies M20. However, all the

tasters found that there was a difference between cookies CPO16 and the control cookies M20. Thus 20.8%, 35.4% and 43.8% of tasters found that the cookies CPO16 were respectively slightly different, different and very different to the control cookies M20.

## 4. Discussion

### 4.1 Sensory profile of the cookies produced

Lipids generally influence several sensory descriptors of cookies such as colour, texture, mouthfeel, flavour and aroma of food (Maache-Rezzoug *et al.*, 1998; Drewnowski and Almiron-Roig, 2010). The results of the assessment of the intensity of the different descriptors varied from very low intensity (ranking 1 on 5 scales) to medium intensity (ranking 3 on 5 scales). The assessment of the intensity of the colour of the cookie, in this study, agrees with those reported by Yılmaz and Ögütçü (2015) on cookies prepared with wax oleo gels. These authors found the intensity of the colour of the cookies was moderate (Ranking 3 on 5 scales). However, the other descriptors (e.g., aroma and odour) presented a lower intensity than those of Yılmaz and Ögütçü (2015). The results of the assessment of the intensity of the colour of cookies reported in this study show significant variations depending on the incorporation level of each oil used. Similarly, the intensity of several descriptors varied significantly with the level of oil incorporation. This is the case of caramel odour of all cookies, red palm odour of cookies produced with crude palm oil, caramel aroma of all cookies, the aroma of crude palm oil of cookies produced with red palm oil, melting texture of cookies produced with both refined oils, crunchy texture of cookies produced with refined palm oil, sweet taste of cookies produced with refined cottonseeds oil, fat impression of all cookies. A similar effect has been reported for biscuits with variations in the percentages of fat (Drewnowski *et al.*, 1998; Biguzzi *et al.*, 2014). These authors have reported that variations in the percentages of fat in biscuits are perceptible to consumers. On the other hand, the variation of refined oil type (RCO and RPO) was not perceptible to the judges about the assessment of the intensities of all the studied descriptors. However, descriptors such as odour and aroma of vanilla, granular texture, salty and bitter taste and the bitter aftertaste of the produced cookies remained low to very low intensity and without significant variation either according to the type of oil or according to the level of incorporation. Concerning the level of incorporation, the results obtained in this study showed that the cookies with the highest oil content (24%) had the highest intensities of melting texture. This could be justified by the effect of high oil content on cookies melting texture. These results corroborate those reported by Lai and Lin (2006) who

showed that an increase in fat content increases the melting texture of cookies. Similarly, Pareyt *et al.* (2010) reported that decreasing fat content in cookies increases the crunchy texture. Taste plays a very important role in the acceptability of cookies (Chung *et al.*, 2014). The intensity of the three tastes studied did not vary significantly. This could be explained by the constant level of sugar in all cookies. Nevertheless, the sweet taste of cookies RCO16 is significantly different from cookies RCO24. This could be explained by the interactions between refined cottonseed oil and sugar. Previous research of Abdallah *et al.* (1998) has reported that certain lipids enhance the sweetness in cookies and cakes. These lipids promote the release of fat-soluble aromatic molecules that increase the sweetness of food (Pangborn, 1987; Abdallah *et al.*, 1998). As for the assessment of the intensity of fat impression, the results obtained in this study agree with those reported by (Drewnowski *et al.*, 1989; Abdallah *et al.*, 1998; Yackinous and Guinard, 2000) These same authors also reported that the perception of fat in food depends on the level of lipids.

### 4.2 Acceptability of cookies produced

The results of the assessment of the acceptability of the different descriptors stayed middle and varied from rank 2 to 4 on a 5-point hedonic scale. These results are agreed with those of Wani *et al.* (2015), Kuchtová *et al.* (2016) and Roofigari Haghghat *et al.* (2017) on cookies incorporated respectively with whey protein concentrate, white grape and green tea. These authors showed acceptability ranged from 2 to 4 on a scale of 5. In another study by Hama-Ba *et al.* (2019) in Burkina Faso on pancakes and gruel have also obtained hedonic appreciation varying from 3.1 to 4.6 on a scale of 5 (Hama-Ba *et al.*, 2019). The assessment of the acceptability of the cookies produced with the two refined oils is distinct from that of cookies produced with crude palm oil. Cookies RCO20 and RPO20 were the most liked among the cookies produced with the refined oils. Thus, the type of refined oil and the levels 16, 20 and 24% of incorporation did not lead to a significant difference ( $p > 0.05$ ) in the assessment of the acceptability of cookies. These results are similar to those of Costa *et al.* (2019) who work on cookies formulated with goat cream enriched with conjugated linoleic acid. Which mean the changes occurred by the type and the levels 16, 20 and 24% of refined cottonseeds and palm oils were not noticeably perceptible to the judges. For these two refined oils, the best-liked cookies according to the different studied descriptors are in line with the overall assessment of the same cookies. The assessment of the acceptability of cookies in this study shows a link between the different studied descriptors. Several studies

also have reported an interaction between the different sensory descriptors (Benoit, 2004; Drewnowski and Almiron-Roig, 2010). Thus, Benoit (2004) reported that flavour is the combination of the perception of taste, odour and mouthfeel of food. This flavour plays a very decisive role in the overall acceptability of cookies (Chung *et al.*, 2014).

Cookies CPO16 produced with red palm oil were better liked than cookies CPO20 and CPO24. This could be explained by the smallest amount of crude palm oil in these cookies. Red palm oil has a strong smell and aroma of palm, which would not be appreciated by the tasters (Cassiday, 2017). In fact, contrary to cookies produced with the two refined oils, the assessment of the different sensory descriptors of cookies produced with red palm oil was different to that of the overall acceptability of these cookies.

This could be justified by the difficulty to appreciate the different descriptors because of the strong smell and aroma of the red palm oil (Cassiday, 2017). This is in line with the results of the sensory profile for several descriptors which presented significant variations with the refined oils, as opposed to cookies produced with red palm oil (Cassiday, 2017). Thus, the assessment of the acceptability of smell, flavour and fat impression of cookies CPO24 was the most preferred. As for colour, texture and aftertaste, cookies CPO16 were the most preferred. These are in line with the overall appreciation of cookies produced with red palm oil. This also shows the importance of certain descriptors in the acceptability of cookies. Indeed, several studies established the major role of certain descriptors in the acceptability of cookies (Zucco *et al.*, 2011; van der Sman and Renzetti, 2019). These descriptors include colour and texture. The results obtained in this study are in line with the study of Zucco *et al.* (2011).

The Person correlation diagram showed significant correlations between the different studied sensory descriptors (Figure 4). Thus, colour is significantly correlated with five other descriptors (odour, aroma, fat impression, aftertaste and overall acceptability). This shows the importance of colour in the assessment of the acceptability of other sensory descriptors. These results corroborate those of Zucco *et al.* (2011) on wheat cookies enriched with legumes. Indeed, Zucco *et al.* (2011) reported that colour, texture and flavour significantly influence the overall acceptability of baked goods. However, the results of flavour assessment compared to the overall acceptability assessment of cookies produced with red palm oil differed from those reported by Zucco *et al.* (2011). This could be explained by the interactions between the smell and the aroma of red palm oil on the flavour of these cookies. Indeed,

previous work has reported that the flavour of cookies was significantly influenced by other sensory parameters such as smell, aroma and mouthfeel (Pangborn, 1987; Abdallah *et al.*, 1998; Benoit, 2004). After colour, come successively the aftertaste (four significant correlations), flavour and aroma (three significant correlations each), smell and texture (two significant correlations each) and finally the fat impression with one significant correlation. Fat impression showed negative correlations with all other descriptors, but it was only significant with colour ( $P \leq 0.05$ ).

#### 4.3 Classification and paired-comparison test of cookies produced

The result of classifications of cookie agreed with those of overall acceptability assessment. The ranking test showed that the assessment of cookies RCO20 and RPO20 is similar to that of the control cookies M20. The results of cookies with refined cottonseeds and palm oil are similar to those of Costa *et al.* (2019) who indicate that variation of fat type, in cookie formulation, was not perceptible to the judges. The difference test showed that cookies RPO20 were not different to control cookies M20. Cookies RCO20 were slightly different to control cookies M20. The two tests show a significant difference between cookies CPO16 and cookies M20. Cookies RPO16 occupy separate classifications from cookies RCO20, RPO20 and M20.

## 5. Conclusion

This study showed that refined cottonseeds oil, refined palm oils and red palm oil can be used to produce cookies of sorghum. The two refined oils can be used in the same proportions as margarine. For red palm oil, the level of incorporation must be less than 20% to take into account the acceptability of cookies. These three oils are alternatives to margarine, which is more expensive, in the production of cheap sorghum cookies. Among the studied descriptors, colour, texture and fat impression had most influenced the consumers' preferences. The acceptability of fat impression had a significant and negative correlation with the acceptability of colour ( $r = 0.72$ ); while colour, odour, aroma, taste, bitter after taste and overall acceptability had a significant and positive correlation.

### Conflict of interest

The authors declared no conflict of interest.

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