ABSTRACT

**Aims:** Lipids have important role in cookies production depending on their nature and function. In this study, the effect of refined cottonseeds oil (RCO), refined palm oil (RPO), and red (or crude) palm oil (CPO) on physicochemical characteristics of gluten-free sorghum cookies was evaluated and compared to control gluten-free cookies produced with a margarine (M20).

**Methodology:** RCO and RPO were incorporated at the level of 20 % and CPO at the level of 16%. The physicochemical characteristics were determined according to standard methods of analysis.

**Results:** Moisture, ash, proteins, lipids, sugar, fiber, pH, fat acidity, and energy value were ranged respectively between 0.12 ± 0.05 and 1.72 ± 0.02 %; 2.00 ± 0.00 and 2.34 ± 0.01 % (g/100g DM); 6.91 ± 0.08 and 7.49 ± 0.07 % (g/100g DM); 20.61 ± 0.01 and 25.62 ± 0.53 % (g/100g DM); 61.71 ± 0.52 and 65.79 ± 0.23 % (g/100g DM); 3.41 ± 0.52 and 8.02 ± 2.04 % (g/100g DM); 7.01 ± 0.00 and 7.36 ± 0.00; 0.03± 0.00 and 0.11 % of H2SO4; 462.70 ± 8.17 and 505.79 ± 5.32 Kcal. The use of RCO and RPO induced significantly increase of the fat content. But, the moisture, ash, fat, sugar and the energy of the experimental and control cookies are in accordance with the recommended

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value of the guidelines of codex Alimentarius on supplementary foods for older infants and young children.

**Conclusion:** RCO, RPO and CPO exhibit the potential to be used as substitutes to margarine in the production of gluten-free cookies with interesting nutritional values.

**Keywords:** Cottonseeds oil; palm oil; gluten-free sorghum cookies; physicochemical characteristics; Burkina Faso.

1. **INTRODUCTION**

The market of gluten-free products is more and more increasing worldwide due to the obvious gluten role in public health concerns including food allergies, coeliac disease and gluten sensitivity [1,2]. However, finding the best gluten-free flours for the substitution of traditional gluten rich flours such as wheat, rye, barley, oats while keeping overall characteristics known of traditional cookies including good flavors, long shelf life, pleasant aroma and taste, continues to be a major challenge for food scientists.

Cookies are high-energy density foods and widely consumed by the population in the world. These ready-to-eat foods are characterized by their low cost, their high nutritional quality, their pleasant tastes and long shelf life [3,4]. Flour, sugar, and fat are the main ingredients in cookie’s formulae [5,6]. However other minor ingredients including yeast, baking powder, salt, emulsifier, milk, flavoring agent, and sodium metabisulphite are also used in cookie’s formulae [4,6].

Several researchers studying gluten-free cookies have used various wheat flour replacers such as rice, maize, sorghum and pearl millet flours [7,8,9] or a mixture of gluten-free flours (brown rice flour, soya flour, buckwheat flour and millet flakes) and starches (corn starch, potato starch) [10]. However, none of those studies analysed the characteristics of gluten-free cookies processed with different local vegetable oil sources.

Fats and oils play an important role in the technological process of cookies due to their involvement in the air cell size reduction [11,5]. These macro-molecules, often interact with non-fat components to influence the texture of food by the formation of structures of crystalline networks [12,5]. The quality of the final cookies including taste, texture, shelf life, and the cost are close to the quality of fats used in cookie processing [13,4]. In cookies’ formulae, fats control the texture, oxidation stability and plasticity of cookies [14-16]. Solid fats are important in cookie processing in order to meet specific requirements of oxidation stability and functional properties of texture (crisp, crunchy or fondant). This leads to the use of hydrogenated vegetable fats. The purpose of the hydrogenation being to saturate the double bonds of unsaturated fatty acids and to increase the « solid »/« liquid » ratio [16]. Due to the specific role of the source of this fat [14,17], processing cookies using other sources of fat, is another major challenge for food scientists [16].

In Burkina Faso, like in some developing countries, margarine is the main source of fat commonly used for the cookies processing [8,9]. However, margarine is imported into most parts of developing countries and is consequently not always accessible to the overall population [18,19]. On the other hand, some other sources of fat such as palm oil and cottonseed oil are more accessible to the poorest people. Also, our earlier work [20] therefore evaluated the effect of refined cottonseed oil (RCO), refined palm oil (RPO) and crude palm oil (CPO) and their level of incorporation on sensory quality of sorghum cookies have presented good acceptability. The aim of the present study was to evaluate the RCO, RPO, and CPO on the physicochemical characteristics of sorghum cookies comparatively to a margarine (M20) cookies.

2. **MATERIALS AND METHODS**

2.1 **Raw Materials**

The raw materials used in the preparation of gluten-free cookies were Sorghum (Sorghum bicolor Var. Gampela) grains, RCO, RPO, CPO, M20, sugar, powdered milk, eggs, salt, vanilla sugar, baking powder and maize starch. These ingredients were purchased in the local market.

2.2 **Formulation and Processing Methods of Cookies**

Sorghum grains were processed into flour after shelling and milling and the cookies were produced according to the method described by Songré-Ouattara et al. [9] (Fig. 1) in the Food
Technology Department (DTA) of Research Institute for Applied Sciences and Technologies (IRSAT) at Ouagadougou. Briefly, the oil and sugar were mixed for 5 minutes in a Krups brand kneader. The eggs, vanilla sugar, and salt were successively added and kneaded. Sorghum flour, powdered milk and corn starch were mixed well before adding to the previous mixture. After this, all was kneaded for 10 minutes. The doughs obtained were laminated and molded using cookies cutters. The dough pieces obtained were baked in a local oven preheated to 135°C. The cookies were baked for 40 minutes, and cooled in a room at a temperature of 28°C. After production, cookies were manually 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. All samples were analyzed before two weeks of storage.

RCO, RPO and M20 are incorporated at the level of 20% (RCO20, RPO20 and M20) whereas the crude palm oil is of 16% (CPO16). Among the cookies prepared, those containing M20 were the control samples. The cookies formulas were given in Table 1. The composition of margarine used to produce control cookies, as indicated on the package, is: water, vegetable oils (Palm oil and Palm Olein) -20%, Salt (<3%), Emulsifiers (monoglyceride, PGPR, fully hardened rapeseed oil), Preservatives (potassium sorbate and/or sodium benzoate), Vitamins (A, D, E, Niacin, Folic, B6, B12), Acidifier (citric acid), Artificial creamy flavors, antioxidant (EDTA) and colorant (beta carotene).

2.3 Physicochemical Analysis

Protein, lipid, ash, and moisture contents were determined according to the Association of Official Analytical Chemist (AOAC) Methods [21]. The total sugars were quantified according to Montreuil and Spik’s methods [22].

The crude fibers were obtained from the differential method described by Le Gall et al. [23]. The energy value of cookies was calculated using Atwater and Benedict’s coefficients according to the following formula:

\[ \text{Energy (Kcal/100 g) = } \% \text{ glucids} \times 4 \text{ (Kcal)} + \% \text{ proteins} \times 4 \text{ (Kcal)} + \% \text{ lipids} \times 9 \text{ (Kcal)} \]

The pH was determined according to the method described by Nout et al. [25]. The fat acidity of the cookie was determined according to the French standard method ISO 7305 [26].

2.4 Data Analysis

Data were collected using Microsoft Excel 2016. Analysis of variance (ANOVA) was performed by Fisher test. The Principal Component Analyses (PCA) on the physicochemical composition of the fourth (4th) cookies was performed using XLSTAT software, version 2016.02.27444. All analysis was done in three replications.

3. RESULTS AND DISCUSSION

3.1 Presentation of Cookies

Four (4) samples of cookies were obtained: one cookie for each of the three oil types tested (RCO20, RPO20 and CPO16) and the control cookie produced with a margarine (M20). The fig. 2 showed the two faces of the four cookies produced.

3.2 Physicochemical Composition of the Cookies

The physicochemical composition of the cookies is shown in Table 2. The moisture content of the cookies with RPO20 (1.92 ± 0.02%) was the highest whereas the cookies with RCO20 presented the lowest moisture content (0.12 ± 0.05%). The highest moisture content of RPO20 cookies may be linked to the high water-binding capacity of these cookies. The high water-binding capacity of these cookies is induced by the RPO20 as already reported by several authors [25,26]. Overall, the moisture content of all the cookies was in line with the guidelines (≤ 5%) of Codex Alimentarius on formulated supplementary foods for older infants and young children [27] as moisture content of all of them was less than 2%. This finding of low moisture content is one of the main goals targeted in cookies processing as low moisture content in foods is not favorable for microbial growth and could lead to a long shelf life of cookies [28].

The ash content of the cookies was around 2%. This value is similar to the results of Songré-Ouattara et al. [8,9]. These authors have reported ash content going of 2% to 4% on sorghum cookies produced with a margarine. This is in line with the value of the guideline of codex Alimentarius [27] which recommends a value under 3 (≤ 3).
Table 1. Cookies formulas

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Proportion of raw materials (%)</th>
<th>CPO16 cookies</th>
<th>RCO20, RPO20, and M20 cookies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>56.9</td>
<td>52.9</td>
<td></td>
</tr>
<tr>
<td>lipid</td>
<td>16</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Powder sugar</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Egg</td>
<td>7.3</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Maize starch</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Powder Milk</td>
<td>1.7</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Baking powder</td>
<td>1.7</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Vanilla sugar</td>
<td>1.3</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Salt powder</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Distilled water (ml)</td>
<td>300</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>

RCO20: refined cottonseed oil at 20%; RPO20: refined palm oil at 20%; CPO16: crude palm oil at 16%; and M20: Margarine at 20%

Fig. 1. Diagram of cookie’ production adapted from Songré-Ouattara et al. [9]

Fig. 2. The two faces of the four cookies produced
However, the ashes content found in this study were less than the ash content of some local infantile flours including Misola (3.30 ± 0.01) [29]. The ash content of the control cookies (M20) and the cookies produced with CPO were the highest (2.34 ± 0.01). This variability could be explained by the quality of the two investigated lipids. Indeed, the margarine used in the production of control cookies contains an additional mineral element as mentioned in the margarine composition. Also, the CPO used is a crude oil comparatively to the two other refined oil (RCO and RPO) and so the refining has eliminated the mineral elements.

The pH of the cookies ranged from 7.01 ± 0.01 for CPO16 cookies, to 7.36 ± 0.00 for RCO20 cookies. There was significant difference (p >0.05) between the pH value of the different cookies. This difference might be due to the variation in the moisture content of the cookies. The pH found in this study was lower than those obtained by Pourmohammadi et al. [30]. These authors have reported pH values ranging from 7.50 to 8.40 for wheat-based cookies [30]. Nevertheless, the pH value found in this study was higher than the pH value reported by Vatankhah et al. (6.55, 6.62 and 6.81) [31] and Nabil et al. (2020) (5.06 and 6.33) [32] on wheat-based cookies.

The lipid content of the control cookies (M20) and CPO16 was the lowest, 20.82 ± 0.08 and 20.61 ± 0.01% respectively. These values were also similar to that of Songré-Ouattara et al. [8, 9]. These authors have reported 20.9 ±1.4% as lipid content of their cookies. Therefore, the lipid content of the cookies produced with refined oils was higher than those of Songré-Ouattara et al. [8,9]. The lowest content of lipids in cookies M20 and CPO may be due to the fact that margarine contains other elements (minerals, emulsifiers, acidifiers, colorant, etc.) and CPO have been used at the level of 16% comparatively to other oils (RCO and RPO) that were used at the level of 20%; whereas in refined oil there are more lipids molecules. Songré-Ouattara et al. [8,9] have used margarine in the production of their cookies, this explained the similarity of the lipids content of the control cookies M20 and those of Songré-Ouattara et al. [8,9]. Only the lipid content of cookies produced with RPO (25.62 ± 0.53%) was over to the recommended value of the guidelines (10-25%) of codex Alimentarius on supplementary foods for older infants and young children [27].

The fat acidity of the cookies varied from 0.03 to 0.11 g of H2SO4 for 100 g of cookies. The CPO cookies showed the high fat acidity (0.11 g of H2SO4 for 100 g of cookies). This could be due to a previously high hydrolysis of the fatty acids contained in this oil or a high hydrolysis during the processing of cookies. The fat acidity of cookies conventionally represents the free acids extractable by ethanol 95% at ambient laboratory temperature. The CPO cookies would therefore be less suitable for storage compared to control cookies (M20), RCO and RPO cookies. The fat acidity of M20, RCO and RPO cookies are similar to those found by Songré-Ouattara et al. [9] on sorghum cookies (0.02 to 0.03 g of H2SO4 for 100 g of cookies) and sorghum cookies enriched with spirulina (0.03 to 0.05 g H2SO4 for 100 g of cookies). The CPO cookies have fat acidity higher than these cookies but similar to sorghum cookies enriched with moringa [9]. The fat acidity of all the cookies produced were less than those found by Kumar et al. on cookies produced with refined wheat flour. These authors found fat acidity varying from 0.36 to 0.85 on oryzanol fortified cookies [33].

The protein content of the control cookies M20 and the cookies CPO produced with the red palm oil were the highest. There was no significant difference (p <0.05) between the protein content of cookies M20, RCO, and CPO. The protein content of the two cookies RPO and RCO, produced with refined oil were not significantly different (p <0.05). But the protein content of the cookies RCO was significantly different from those of control cookies M20 and cookies CPO. This may be due to the fact that the margarine and CPO used for the production of these cookies must have nitrogen compounds. The proteins content of cookies RCO are similar to those found by Songré-Ouattara et al. [8]. All the protein contents of the cookies are less than the recommended value of the guidelines (≥15%) of codex Alimentarius on supplementary foods for older infants and young children [27].

The sugar content of margarine (M20) cookies was the highest and was significantly different (p >0.05) from cotton (RCO) and palm (RPO and CPO) oils cookies. But all the sugar contents were in line to the recommended value of the guidelines (64±4%) of codex Alimentarius on supplementary foods for older infants and young children [27].

The fiber content of the cookies varied from 3.41 ± 0.52% (RCO cookies) to 8.02 ± 2.04% for CPO cookies. The CPO cookies presented the highest
content of fiber (8.02 ± 2.04\%) and were significantly different (p >0.05) from control cookies M20 and the two other cookies (RCO and RPO). This may be due to the fact that the CPO used is not refined and should contain fiber elements. Indeed, the object of refining is to eliminate some elements contained in the fatty materials, including the fibers. The RCO and RPO cookies have presented a content of fiber not significantly different (p <0.05) to control cookies (M20). The fiber contents of the cookies are higher than several wheat cookies that are less than 2\% [34-36]. They were also higher than other gluten free cookies, such as rice (1.98 to 2.61\%) [37-39], maize (0.24 to 0.26) [16], etc.

3.3 Principal Component Analysis of the Physicochemical Composition of the Cookies

The Principal Component Analysis (PCA) performed on the physicochemical composition of the cookies is presented in Fig. 3. This representation showed that the first two axes explained 87.36\% of the variation observed with 52.22\% of variation associated to axis 1 and 30.14\% to axis 2. The dispersion along axis 1 was mainly related to moisture, fat, protein, energy, and pH; while the dispersion along axis 2 was mainly linked to variation in ash, sugar, and crude fiber (Table 3). Axis 1 shows that cookies CPO are highly rich source of fiber and poor source of sugar and ash; but the control Cookies M20 are rich in sugar and ash and poor in fiber content (Fig. 3). Axis 2 shows that the RCO and RPO cookies are rich sources of fat and energy and have pH, but poor in protein and moisture content (Fig. 3).

3.4 Energy Density of the Cookies

The energy value of the cookies varied from 462.70 ± 8.17 (CPO) to 505.79 ± 5.32 Kcal/100g Kcal / 100g (RPO). The CPO cookies presented the least value of energy due to the fact that these cookies presented the high rate of fiber which did not contribute to energy value. All the cookies presented high energy value and were higher than the recommended value of the guidelines of codex Alimentarius (400-425 Kcal / 100g) on supplementary foods for older infants and young children [27].

<table>
<thead>
<tr>
<th>Table 2. Physicochemical characteristics of cookies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cookie Parameter</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Moisture (%)</td>
</tr>
<tr>
<td>Ashes (%)</td>
</tr>
<tr>
<td>Lipids (%)</td>
</tr>
<tr>
<td>Proteins (%)</td>
</tr>
<tr>
<td>Sugars (%)</td>
</tr>
<tr>
<td>Fibers (%)</td>
</tr>
<tr>
<td>Energy (Kcal/100g)</td>
</tr>
<tr>
<td>Fat acidity (% of H(_2)SO(_4))</td>
</tr>
<tr>
<td>pH</td>
</tr>
</tbody>
</table>

\(^*\) : guidelines of codex Alimentarius on supplementary foods for older infants and young children [27]; RCO: refined cottonseed oil; RPO: refined palm oil; CPO: crude palm oil; and M20: Margarine

<table>
<thead>
<tr>
<th>Table 3. Contribution of parameters in the formation of the axes of the PCA analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Moisture</td>
</tr>
<tr>
<td>Ash</td>
</tr>
<tr>
<td>Fat</td>
</tr>
<tr>
<td>Protein</td>
</tr>
<tr>
<td>Sugar</td>
</tr>
<tr>
<td>Energy</td>
</tr>
<tr>
<td>Fiber</td>
</tr>
<tr>
<td>pH</td>
</tr>
</tbody>
</table>

\(F1\): axis F1; \(F2\): axis F2
Fig. 3. Principal Component Analysis (ACP) distribution of the physicochemical composition

The energy values of the different cookies are similar to the energy value of sorghum cookies enriched by spirulina and moringa which varied from 489 to 518 Kcal / 100 g [8]. RCO and RPO cookies presented no significant difference for the energy value. This can be due to the fact that these cookies have presented the higher content of lipid that induces high energy content.

4. CONCLUSION

Gluten free cookies with total substitution of margarine by refined cottonseeds oil, refined palm oil and red palm oil were produced successfully. The cookies produced with crude palm oil presented most difference with the control cookies than the refined oil cookies. Therefore, the cookies produced with the two refined oils are different to control cookies by the fat content. These three oils showed potential as alternatives to margarine, which is more expensive, in the production of gluten free sorghum cookies.

ACKNOWLEDGEMENTS

The authors thank the National Fund for Research and Innovation for Development (FONRID) by supporting this work through the Biscuit Production Support Project.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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