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Health Quality Assessment of Refined Cottonseed Oils Produced in the Industrial Zones of Ouagadougou and Bobo-Dioulasso in Burkina Faso

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Abstract

Cottonseed oil is one of the most widely consumed oils in Burkina Faso. Its production evolved from small-scale to industrial production to offer a high-quality refined oil. However, if the refining process is not well controlled, the oil could present a danger to consumers. Therefore, control of the health quality of these oils is necessary. This study was therefore undertaken, and its objective was to evaluate the health quality of cottonseed oils produced in the industrial zones of Ouagadougou and Bobo-Dioulasso, in Burkina Faso. The analyses focused on chemical contaminants and physicochemical quality. The gossypol content was determined by High Performance Liquid Chromatography, and standard methods ISO 3960 and ISO 660 were used to evaluate peroxide value and acid index, respectively. As for chemical contaminants, they were evaluated according to the QuEChERS NF 15662 method for pesticides and by flame atomic absorption for metallic trace elements. The results show an average acid index of 0.23 mg KOH/g, in line with standards, and a peroxide value above the limit in 18.75% of samples, with an average of 7.01 meqO_2/Kg. None of the samples contained gossypol, pesticides, lead, or cadmium, thus complying with current health quality standards.

Keywords

Refined Oil, Cottonseed, Health Quality, Gossypol, Burkina Faso

1. Introduction

Agriculture is the main pillar of development in many countries around the world. In developing countries, the livelihoods of rural and poor households depend largely on agriculture, which provides them with food as well as income [1].

In these countries, cash crops like cotton play a crucial role in income generation and economic development. Different varieties of cotton, such as *Gossypium hirsutum*, *Gossypium arboreum*, *Gossypium herbaceum*, *Gossypium barbadense*, and others, are produced for use in textiles, fibers, oils, and animal feed [2].

In Burkina Faso, cottonseed is the most widely used raw material for the production of edible oil and animal feed by mechanical extraction and chemical refining. National cottonseed oil production in 2018 was estimated at 50,000 tons, while annual demand was 100,000 tons [3]. In May 2021, there were 138 oil mills, 73 of which are approved, with 80% located in the industrial zones of Ouagadougou and Bobo-Dioulasso. However, the transformation of cottonseed into edible oil is risky if the refining process is not properly controlled. The aim of refining is to maintain or improve the physicochemical and nutritional qualities of the oil. Several stages are used during refining to eliminate undesirable compounds [4].

Poor refining can degrade the physicochemical quality of the oil, as well as lead to the presence of contaminants such as gossypol, a naturally toxic compound found in cotton seeds, pesticides, and heavy metals. These substances can cause serious health problems for consumers.

The objective of this study is to assess the sanitary quality of refined cottonseed oils produced in the industrial zones of the cities of Ouagadougou and Bobo-Dioulasso in Burkina Faso.

2. Materials and Methods

2.1. Plant Material and Study Setting

The plant material was refined oil from *Gossipium* sp. Samples were collected in the industrial zones of the cities of Ouagadougou and Bobo-Dioulasso in Burkina Faso. Laboratory analyses were carried out at the National Agency for Environmental, Food, Work, and Healthcare Product Safety (ANSSEAT), formerly the National Public Health Laboratory (LNSP) in Ouagadougou.

2.2. Sampling

Cottonseed oil samples were collected in the industrial zones of Burkina Faso's two largest cities, Ouagadougou and Bobo-Dioulasso. In addition, other cottonseed oil samples received at the laboratory for analysis were used in the study. A total of 32 cottonseed oil samples were analyzed, including 10 samples from Bobo, 10 from Ouagadougou, and 12 others among those received by the laboratory for routine testing. Samples were collected from cottonseed oil refining facilities in accordance with ISO Standard 5555. Sampling was therefore carried out in a balanced manner across the areas to ensure good coverage. The oils were packaged

in 350 mL amber bottles and sent to the laboratory, where they were stored at laboratory temperature and tested during the first week.

2.3. Evaluation of Contaminants and Chemical Composition of Refined Cottonseed Oils

2.3.1. Pesticides Quantification

Quantification of pesticides in cottonseed oils was carried out using the QuEChERS NF 15662 method as described by [5] with slight modification. It is based on a test sample of 0.5 g of oil in a 50 mL Falcon tube, to which a mixture of solvent and extraction kit has been added. After vortexing and centrifuging, the mixture is run through a pre-conditioned purification kit, then eluted with solvents before undergoing dry evaporation. The residue is then eluted with 0.5 mL isooctane for gas chromatographic reading. A calibration curve was performed using a multi-standard solution mixture containing 49 pesticides at a level of 5 ppm. Serial dilutions were performed to obtain daughter solutions with concentrations of 0.01 ppm, 0.02 ppm, 0.04 ppm, 0.08 ppm, and 0.16 ppm for the calibration curve. To ensure the absence of a matrix effect, a comparison was made between the responses of the standards in solution and those of the matrix-matched standards.

2.3.2. Determination of Heavy Metals

The determination of heavy metals (Lead, Cadmium, Chromium) was carried out according to the method described by [6]. A test sample of 1 g of cottonseed oil was introduced into a test tube, then 10 mL of concentrated nitric acid and 2 mL of hydrogen peroxide were added. The mixture was then placed in a digestion/mineralization block and heated until a clear liquid was obtained. After cooling, the solution was filtered through a 0.45 µm ashless filter paper into a 50 mL Falcon tube, followed by dilution for flame atomic absorption (FAA) reading.

2.3.3. Determination of Chemical Composition

Determination of chemical composition was carried out by chemical screening using the method described by [7]. A sample of cottonseed oil was solubilized in an acetone solution, and 1 µL of the mixture was injected into the GC-MS. The NIST and Wiley libraries were then used to identify the various molecules.

2.4. Evaluation of Physicochemical Quality of Refined Cottonseed Oils

2.4.1. Determination of Moisture and Volatile Matter Content

The moisture and volatile matter content was determined by oven drying at 105˚C using the standard ISO 662:2016. Three determinations were carried out for each sample.

2.4.2. Determination of Peroxide Value

Peroxide value was determined using ISO 3960:2007. 2 g of oil were weighed into a stoppered Erlenmeyer flask. Next, 10 mL of chloroform, 15 mL of acetic acid, and 1 mL of saturated potassium iodide solution were added, then stirred for 1 minute.

The mixture was placed in the dark for 5 minutes. Finally, 75 mL of distilled water was added, and the mixture was titrated with 0.01 N sodium thiosulfate in the presence of starch.

A blank test was carried out under the same conditions, and the peroxide value was calculated using the following formula:

$$PV = \frac{(Ve - Vb) \cdot N}{PE} * 1000 \quad (1)$$

PV: Peroxide value;

Ve: Volume of sodium thiosulfate used for the sample;

Vb: Volume of sodium thiosulfate used for blank test;

PE: Sample weight.

2.4.3. Determination of Acid Index

The acid index was determined using the ISO 660:2020 standard. A test sample of 10 g of oil was brought into contact with a mixture of 50 mL of ethanol and diethyl ether (50:50), and the solution was then titrated with alcoholic potassium hydroxide solution in the presence of phenolphthalein as an indicator until the color changed to pink. The acid index was calculated using the following formula:

$$AI = \frac{V * N * 56.11}{PE} \quad (2)$$

AI: Acid index;

V: KOH Volume;

N: Normality of KOH solution;

PE: Sample weight.

2.4.4. Determination of Refractive Index

The refractive index provides information on the type of fat. It defines the ratio between the speed of light in a vacuum and the speed of propagation in the substance at a defined wavelength. Measurements were taken using a Metler Toledo, RE40 Model refractometer, at a temperature of 40˚C, in accordance with ISO 6320:2017.

2.4.5. Determination of Iodine Index

The iodine index is used to determine the number of double bonds present in a fatty acid. It measures the degree of unsaturation of the fat. The iodine index of the samples was determined using the method described by [8], for which a relationship exists between the refractive index and the iodine index in the oil, and expressed by the following equation:

$$II = RI * 8555.559 - 12425.928 \quad (3)$$

II: Iodine index;

RI: Refractive index.

2.4.6. Determination of Gossypol Content

Free and total gossypol contents were determined according to the method de-

scribed by [9], with a few modifications.

The principle of the method is based on dissolving samples of refined cottonseed oil in a mixture of reagents, followed by the hot extraction of gossypol. After cooling and dilution, gossypol is quantified at 254 nm using high-performance liquid chromatography coupled to a DAD detector. For total gossypol determination, 0.5 g of refined cottonseed oil was introduced into test tubes for each sample. Then, 2 mL of complexing reagent (4 mL 3-amino-l-propanol and 20 mL glacial acetic acid, introduced into a 200 mL flask and filled up to 200 mL with N,N-dimethylformamide) was added, and the mixture was left in a 95˚C water bath for 30 min. After cooling, 10 mL of mobile phase (methanol/water (87:13) acidified to 0.1% with H3PO4) was added, followed by filtration using Wattman N˚2 filter paper and 0.45 µm syringe filter, then injected into the HPLC for detection and quantification.

For free gossypol determination, 0.5 g of refined cottonseed oil was introduced into test tubes, and 5 mL of 70% acetone was added, and the mixture was stirred for one hour. After stirring, the mixture was filtered through N˚2 filter paper, then 2 mL of the filtrate was introduced into another test tube containing 2 mL of complexing reagent. The mixture was then heated in a 95˚C water bath for 30 minutes. After cooling, the solution was brought to a total volume of 10 mL with the mobile phase before being filtered through a 0.45 µm syringe filter for injection.

For chromatographic analysis, the filtrate from the various refined cottonseed oil samples obtained was placed in vials for analysis using Agilent Technologies 1100 series HPLC coupled with a DAD detector. Injection volume was set at 50 µL and a constant mobile phase flow rate of 1 mL/min in isocratic mode. Chromatographic separation was performed using a ZORBAX Eclipse XDB-C18 column (4.6 × 250 mm, 5 µm) (Agilent, USA), and the detection wavelength was set at 254 nm.

Standards of (±)-Gossypol from cotton seeds, purity ≥ 95% (HPLC) were purchased from Sigma-Aldrich Co., 3050 Spruce Street, St Louis, MO 63103 USA. 5 mg test portion of the gossypol standard was dissolved in a 5 mL volumetric flask and made up to the mark with the complexing reagent and volumes of 50 µL, 100 µL, 200 µL, 300 µL, and 500 µL of the stock solution were then prepared in a 10 mL volumetric flask for the calibration curve (**Figure 1**). The regression equation and correlation coefficient of gossypol were $y = 0.0042x + 1.5819$, $R^2 = 0.9989$ respectively, indicating good linearity.

2.5. Statistical Data Analysis

Statistical analyses were performed using XLSTAT software. All results are expressed as the mean ± standard deviation of three replicates per measurement. The data underwent analysis using both analysis of variance (ANOVA) and principal component analysis (PCA). Tukey's test ($p < 0.05$) was used to ascertain significant differences between means, with XLSTAT software employed for this purpose.

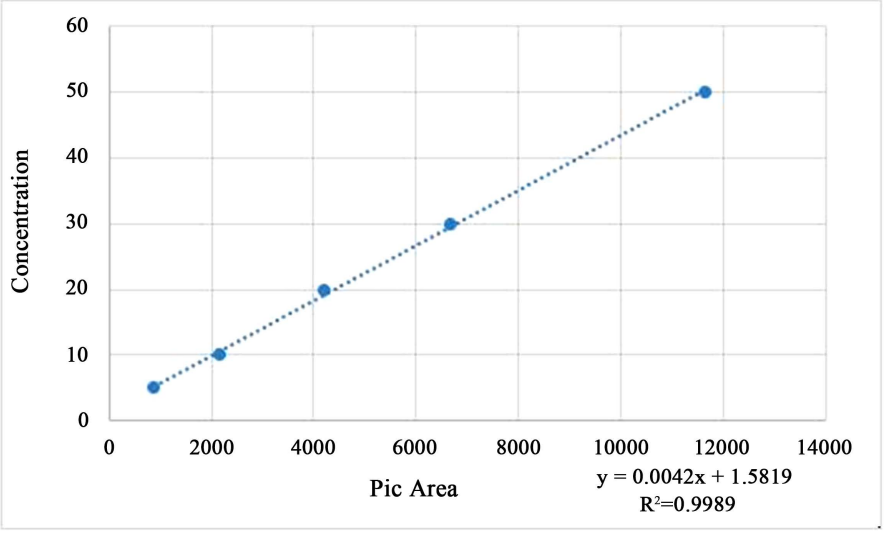


Figure 1. Calibration curve for gossypol determination.

3. Results and Discussion

3.1. Results

3.1.1. Physicochemical Quality of Cottonseed Oil Samples

The physicochemical quality of different samples of cottonseed oil is recorded in Table 1. The moisture and volatile matter content in the oil samples varied from 0.015 ± 0.005 to 0.100 ± 0.010 with an average value of 0.055 ± 0.005. The results of the peroxide value show a variation from 2.00 meqO_2/Kg to 13.85 meqO_2/Kg ± 0.61 meqO_2/Kg in the different samples, with an average value of 7.01 meqO_2/Kg. As for the acid index, it varied from 0.060 mg KOH/g to 0.615 meqO_2/Kg ± 0.055 mg KOH/g with an average value of 0.23 mg KOH/g. The refractive index of the various refined cottonseed oil samples ranged from 1.4633 to 1.4651 with an average value of 1.4645, and their iodine index varied from 93.421 to 108.821 with an average value of 104.169.

Table 1. Physicochemical quality of different cottonseed oil samples.

Samples	Peroxide Value (meqO2/Kg)	Acid Index (mg KOH/g)	Moisture Content (%)	Refractive Index	Iodine Index
HCB1	11.73 ± 0.25^{a}	0.165 ± 0.055^{ab}	0.045 ± 0.005^{ab}	1.4647	101.98 ± 0.00^{a}
HCB2	10.75 ± 0.75^{a}	0.225 ± 0.025^{abc}	0.040 ± 0.010^{ab}	1.4646	102.83 ± 0.00^{b}
HCB3	13.85 ± 0.61^{b}	0.395 ± 0.055^{d}	0.085 ± 0.025^{cd}	1.4647	102.83 ± 0.00^{b}
HCB4	8.68 ± 0.19^{c}	0.310 ± 0.030^{cd}	0.095 ± 0.055^{d}	1.4646	102.83 ± 0.00^{b}
HCB5	12.75 ± 0.25^{a}	0.615 ± 0.055^{e}	0.090 ± 0.010^{cd}	1.4644	93.42 ± 0.00^{c}
HCB6	3.75 ± 0.25^{d}	0.235 ± 0.015^{abc}	0.095 ± 0.015^{d}	1.465	103.69 ± 0.00^{d}
HCB7	6.87 ± 0.13^{e}	0.235 ± 0.015^{abc}	0.090 ± 0.020^{cd}	1.4651	104.54 ± 0.00^{e}
HCB8	9.24 ± 0.25^{c}	0.110 ± 0.000^{a}	0.100 ± 0.010^{d}	1.4649	102.83 ± 0.00^{b}

Continued

HCB9	2.88 ± 0.13^{d}	0.195 ± 0.025^{abc}	0.040 ± 0.010^{ab}	1.4646	106.25 ± 0.00^{f}
HCB10	4.38 ± 0.13^{d}	0.365 ± 0.025^{d}	0.055 ± 0.015^{abc}	1.4651	101.98 ± 0.00^{a}
HCO1	7.00 ± 0.51^{e}	0.250 ± 0.030^{abc}	0.040 ± 0.000^{ab}	1.4647	108.82 ± 0.00^{g}
HCO2	7.62 ± 0.13^{e}	0.210 ± 0.010^{abc}	0.045 ± 0.005^{ab}	1.465	107.11 ± 0.00^{h}
HCO3	12.11 ± 0.12^{a}	0.095 ± 0.015^{a}	0.040 ± 0.000^{ab}	1.465	108.82 ± 0.00^{g}
HCO4	5.50 ± 0.26^{f}	0.210 ± 0.010^{abc}	0.040 ± 0.010^{ab}	1.4637	107.97 ± 0.00^{i}
HCO5	7.50 ± 0.26^{e}	0.095 ± 0.015^{a}	0.030 ± 0.000^{a}	1.4645	102.83 ± 0.00^{b}
HCO6	13.75 ± 0.25^{b}	0.210 ± 0.010^{abc}	0.035 ± 0.005^{ab}	1.4645	104.54 ± 0.00^{e}
HCO7	7.37 ± 0.13^{e}	0.210 ± 0.010^{abc}	0.020 ± 0.000^{a}	1.4645	105.40 ± 0.00^{j}
HCO8	8.62 ± 0.12^{c}	0.210 ± 0.010^{abc}	0.015 ± 0.005^{a}	1.4646	104.54 ± 0.00^{e}
HCO9	7.25 ± 0.25^{e}	0.125 ± 0.015^{ab}	0.025 ± 0.005^{a}	1.4644	105.40 ± 0.00^{j}
HCO10	9.00 ± 0.25^{c}	0.070 ± 0.010^{a}	0.050 ± 0.020^{abc}	1.4645	104.54 ± 0.00^{e}
HCL1	3.87 ± 0.13^{d}	0.265 ± 0.015^{bc}	0.050 ± 0.010^{abc}	1.4646	105.40 ± 0.00^{j}
HCL2	8.85 ± 0.12^{c}	0.155 ± 0.015^{ab}	0.020 ± 0.010^{a}	1.4647	104.54 ± 0.00^{e}
HCL3	2.87 ± 0.13^{d}	0.210 ± 0.010^{abc}	0.065 ± 0.035^{bcd}	1.4648	103.69 ± 0.00^{d}
HCL4	2.00 ± 0.00^{g}	0.110 ± 0.000^{a}	0.050 ± 0.000^{abc}	1.4644	103.69 ± 0.00^{d}
HCL5	3.37 ± 0.12^{d}	0.340 ± 0.000^{cd}	0.040 ± 0.000^{ab}	1.4646	103.69 ± 0.00^{d}
HCL6	3.62 ± 0.12^{d}	0.155 ± 0.015^{ab}	0.050 ± 0.020^{abc}	1.4645	96.84 ± 0.00^{k}
HCL7	3.62 ± 0.13^{d}	0.295 ± 0.015^{cd}	0.080 ± 0.000^{cd}	1.4633	107.97 ± 0.00^{i}
HCL8	3.87 ± 0.13^{d}	0.390 ± 0.000^{d}	0.065 ± 0.005^{bcd}	1.4644	107.97 ± 0.00^{i}
HCL9	3.99 ± 0.00^{d}	0.210 ± 0.010^{abc}	0.065 ± 0.005^{bcd}	1.4644	105.40 ± 0.00^{j}
HCL10	8.36 ± 0.13^{c}	0.060 ± 0.000^{a}	0.090 ± 0.010^{cd}	1.4644	104.54 ± 0.00^{e}
HCL11	3.12 ± 0.12^{d}	0.095 ± 0.015^{a}	0.050 ± 0.010^{abc}	1.4643	103.69 ± 0.00^{d}
HCL12	6.10 ± 0.12^{e}	0.490 ± 0.010^{e}	0.045 ± 0.025^{ab}	1.4643	102.83 ± 0.00^{b}
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: Mean ± standard deviation of three replications. Values within the same column with different letters are significantly different at the 5% level according to Tukey's test.

3.1.2. Gossypol Content in Refined Cottonseed Oils

The determination of gossypol content in refined cottonseed oils was validated with a detection limit of 1 ppm and a quantification limit of 2.5 ppm (**Figure 2**). The absorption spectrum of the gossypol molecule was used to validate the analytical results. The spectrum identified (**Figure 3**) is comparable to those found by [10] and [11].

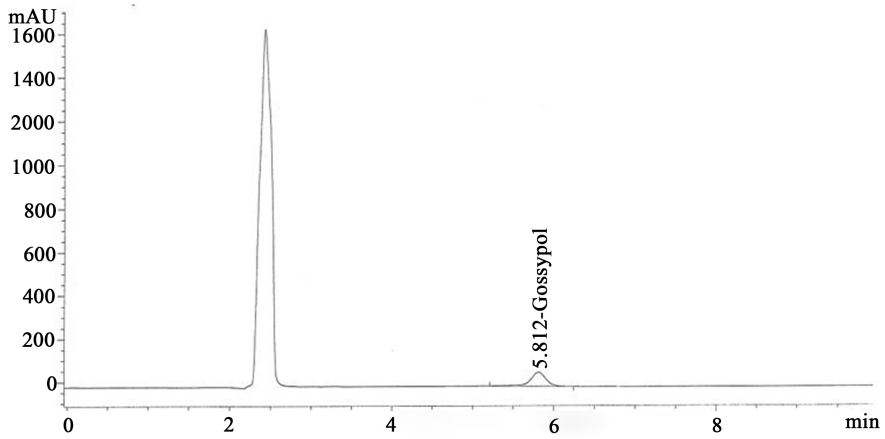


Figure 2. Chromatogram of gossypol standard (2.5 ppm).

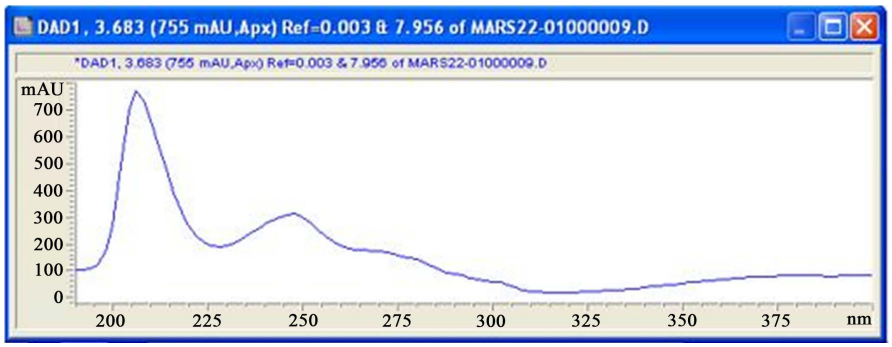


Figure 3. Absorption spectrum of gossypol standard at 5 ppm.

3.1.3. Pesticides Content

Analysis of the various refined cottonseed oil samples revealed pesticide levels below the quantification limit of 0.01 ppm. The various pesticide molecules that were analyzed, depending on the availability of reference standards, were: Methomyl, Carbofuran, Diflubenzamide, Mevinphos, Propoxur, Heptenophos, Ethoprophos, Chlordimeform, Monocrotophos, HCB, Dimethoate, Beta HCB, Quintozene, Lindane, Diazinon, Chlorothalonil, Simazine, Atrazine, Alachlor, Heptachlor, Aldrin, Triadimefon, Pendimethalin, Methazachlor, Penconazole, Thiabendazole, Beta endosulfan, Imazalil, Pretilachlor, Dieldrin, op'-DDT, Benalaxyl, Propiconazol, 2,4'-DDT, Propargite, Carbosulfan, Tetramethrin, Bifenthrin, Methoxychlor, lambda-Cyalothrin, Mirex, Azinphos-Ethyl, Permethrin, Cyfluthrin, Cypermethrin, Alpha-Cypermethrin, PCB N˚209, Deltamethrin, Azoxystrbin. In fact, the levels of pesticides tested for in 100% of the refined cottonseed oil samples were below the limit of quantification.

3.1.4. Heavy Metals Content

Analysis of the various refined cottonseed oil samples revealed an absence of lead, cadmium, and Chromium. However, iron levels ranging from 0.298 mg/kg to 13.294 mg/kg, with an average value of 3.314 mg/kg, were found in 18 samples representing 56.25% of the samples (**Figure 4**).

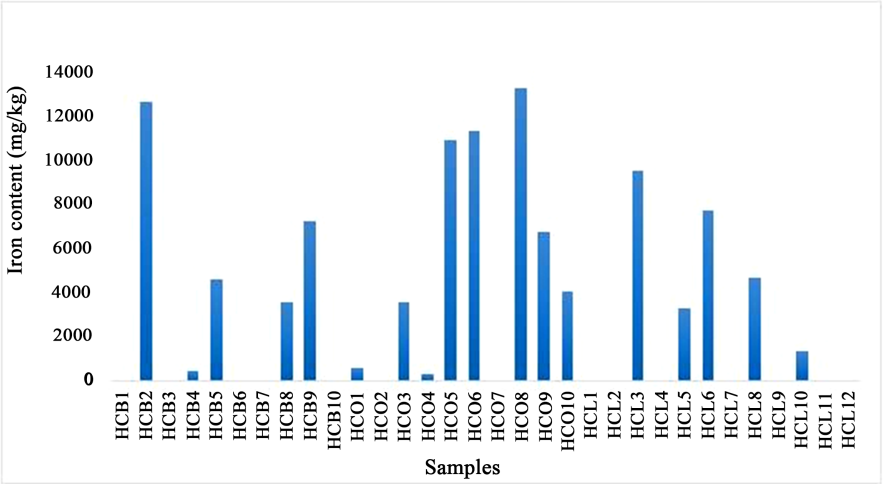
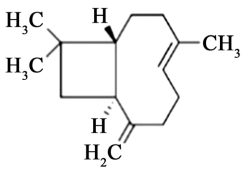
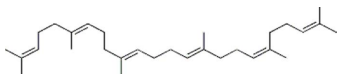
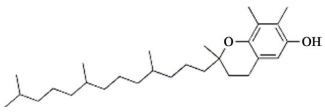
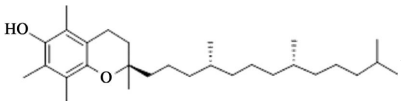
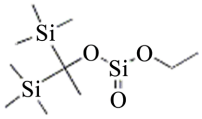


Figure 4. Iron content in cottonseed oil samples.

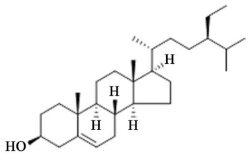
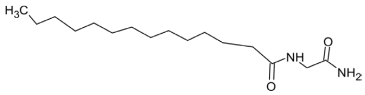
3.1.5. Chemical Composition

Chemical screening revealed the presence of 07 major molecules in refined cottonseed oils. These molecules include trans-caryophyllene, squalene, gamma tocopherol, vitamin E, silicic acid, diethyl bis (trimethyl silyl) ester, beta-Sitosterol, and 2-Myristyl-glycinamide (Table 2).

Table 2. Chemical elements identified in refined cottonseed oil after scanning with GC-MS.

N°	Retention Time	Pic Area	Compound Name	Formula	Heath Interest
01	11.598	3.35	Trans-Caryophyllene		Anti-inflammatory and anticancer properties; cardioprotective, hepatoprotective, and gastroprotective effects
02	29.459	10.72	Squalene		An intermediate metabolite in the synthesis of cholesterol, steroid hormones, and vitamin D; an adjuvant in cancer treatment
03	32.586	8.08	*γ*-Tocopherol		Antioxidant properties
04	33.572	16.34	Vitamine E (*α*-Tocopherol)		Antioxidant properties
05	34.709	3.38	Silicic Acid, Diethyl Bis (Trimethyl Silyl) Ester		Stimulates collagen synthesis

Continued

06	35.787	54.73	Beta-Sitosterol		Prevention of cardiovascular diseases
07	37.431	3.40	2-Myristyl-Glycinamide		Anticancer activity

3.2. Discussion

Principal component analysis (PCA) conducted on cottonseed oil samples (Figure 5) revealed two axes (F1 = 48.26%; F2 = 20.50%) that explain 68.76% of the total data variability. Axis F1 contrasts iodine and refractive index, associated with the degree of lipid unsaturation and chemical composition, with degradation parameters such as moisture, acidity, and peroxide value. Axis F2 mainly distinguishes primary lipid oxidation (peroxide value) from hydrolysis phenomena linked to moisture and acidity. The strong positive correlations between the iodine index and the refractive index indicate that the refractive index is a basic value that relates molecular weight, fatty acids, chain length, and the degree of unsaturation [12].

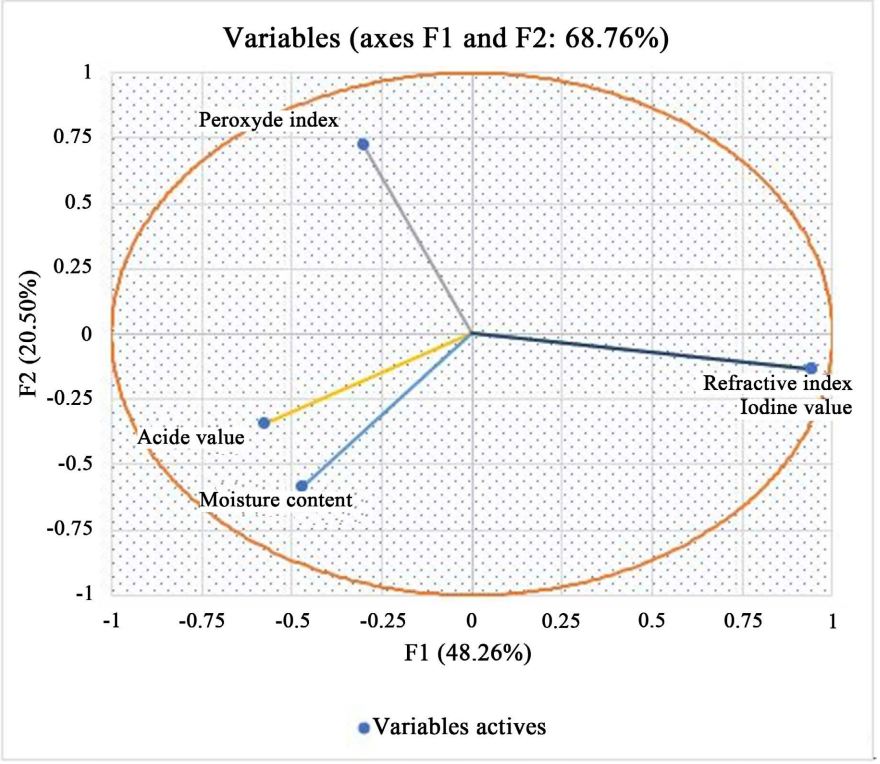


Figure 5. PCA of physicochemical quality of cottonseed oil samples.

The water content of the various samples is lower than that stipulated in national

regulations, which set the water content of refined vegetable oils at 0.2%. These values are significantly lower than those found by [13], who had worked on cottonseed oils produced in Mali. Low water content is essential for oil stability. During technological processing, in particular at the deodorization stage, the moisture contained in the crude oil is eliminated. The presence of moisture promotes the hydrolysis of triglycerides and, consequently, the degradation of the oil. The results obtained, however, reveal variability between samples, which could be explained by insufficient drying and/or deodorization in some cases. Moisture content controls the deodorization stage, which, if mastered, contributes to oil stability and preservation.

Analysis of the peroxide values results shows that 18.75% of the samples do not comply with the National standard of Burkina Faso (NBF) and the Codex Alimentarius standard, which sets the peroxide value at 10 $mEqO_2$/kg of oil. Refined cottonseed oils produced in the cities of Ouagadougou and Bobo-Dioulasso have a lower peroxide value non-compliance rate than that found by [13], who found a 33 % non-compliance rate for cottonseed oils produced in Mali. Also, [14] found very high peroxide values in oil samples collected from markets in Dedougou and Nouna. This shows that oil quality can deteriorate during distribution if the appropriate measures are not applied. High peroxide value in refined cottonseed oils illustrates the onset of oxidation due to contact with atmospheric oxygen. Lipids have an affinity for oxygen, and their oxidation is all the greater the more unsaturated bonds they contain. Polyunsaturated fatty acids and esters are particularly prone to undergo autoxidation [15]. During open drying, under the effect of temperature or malfunction of the deodorizing pump, the oil reacts with oxygen to release oxidation compounds identified as peroxides. High peroxide levels in oils are responsible for alterations in their sensory properties (aroma, odor, texture, color). They also contribute to the loss of nutritional value of these oils. When ingested, oxidized oils can have toxic effects on health. Some of the molecules formed (aldehydes and ketones) are believed to be mutagenic, cytotoxic, carcinogenic, and may lead to neurological or cardiac disorders [14].

All the cottonseed oil samples analyzed complied with the various standards, namely, NBF 01-140: 2009 specifying edible cottonseed oil and Codex, which set the acid index at 0.6 mg KOH/g refined oil. The acid index is used to assess the degree of hydrolysis of the oils, and it reflects the presence of fatty acids in the oil samples. Values similar to these acid indices were reported by [16] on locally produced oils from Benin. In addition, the low acid values of the oils attest not only to the quality of the raw material used, but also to the mastery of the oil refining process. Free fatty acids are eliminated during chemical neutralization. Excessive consumption of oil containing high levels of free fatty acids is thought to promote the onset of cardiovascular disease by increasing plasma cholesterol levels, including Low-Density Lipoprotein (LDL) cholesterol, considered a major risk factor [17].

All samples of refined cottonseed oil complied with NBF 01-140: 2009 and CODEX STAN 210-1999 rev. 2022 for the Standard for Named Vegetable Oils. The

refractive indices provide information on the purity of the samples taken and show that they have not been adulterated [8]. The refractive index also depends on the oil's chemical composition and temperature [18].

Over 93.75% of the samples analyzed had an iodine index in compliance with NBF 01-140: 2009, which sets the value between 100 and 123. These values are also similar to those found by [19]. The iodine index provides information on the degree of unsaturation of the fatty acids contained in the oil, whose importance in humans is well established. Indeed, unsaturated fatty acids have a favorable effect on the lipid profile, lowering LDL-cholesterol levels and thus helping to reduce the risk of cardiovascular disease [20]. The iodine index is directly related to the degree of oxidation of an oil. Specifically, oxidation leads to the loss of double bonds, resulting in a lower iodine index. The more unsaturated the oil, the higher its iodine index [21]. These values are significantly higher than those found by [22]. This testifies to the technical capacity of the oil mill industry in Burkina Faso to supply consumers with higher-quality cottonseed oil.

Analyses showed that all samples of refined cottonseed oil had gossypol levels below the detection limit of 1 ppm. This result is similar to that of [23] [24], whose free gossypol and total gossypol were not detected in refined cottonseed oils. The gossypol content of cottonseed oils complied with NBF 01-140: 2009, which specifies edible cottonseed oil. Indeed, none of the samples analyzed had a peak with a spectrum similar to the gossypol molecule and comparable to the spectrum pattern identified by [10] [11]. This proves that all refining units use a good refining process, leading to the elimination of gossypol. Furthermore, according to [25], various physical, chemical, and biological treatments lead to a significant reduction in gossypol levels in cottonseed co-products. In refining units in Burkina Faso, gossypol is mainly eliminated during chemical neutralization by the use of alkalis or alkaline salts that remove gossypol in addition to free fatty acids [26].

The absence of pesticides in refined seed oils could be explained by their elimination at the end of the refining process. In fact, chlorinated pesticides are completely eliminated during deodorization, provided the temperature is at least 230˚C [27]. These results concur with those of [28], according to whom few crude vegetable oils had pesticide residue levels below 0.01 ppm and needed to be refined to comply with maximum permitted limits. Pesticides can be harmful to animal and human health. They are mainly lipophilic and accumulate in human body tissues. They can be responsible for dermatological, mutagenic, carcinogenic, teratogenic, and neurological effects, as well as hormonal disorders [29].

Analysis of the various samples of refined cottonseed oil revealed an absence of lead, chromium, and cadmium. These results differ from those found by [6], who reported values ranging from 0.34 mg/kg to 2.77 mg/kg for lead and 0.01 mg/kg to 0.34 mg/kg for cadmium. The iron levels found in the samples were lower than those reported by [30], who found levels ranging from 52 to 291 mg/kg in various refined oil samples, namely olive, hazelnut, sunflower, and corn oil. Of these samples, four complied with the maximum limits of 1.5 mg/kg for iron, 0.1 mg/kg for lead, and 0.2

mg/kg for cadmium set by CODEX STAN 210-1999. The presence of trace metals in vegetable oils depends on several factors, such as the plant species, the soil used for cultivation, the nature of the water, the variety, and the stage of development of the plant [31]. High levels were also reported by [32], who found lead levels ranging from 8.546 mg/kg to 18.783 mg/kg and from 1.321 mg/kg to 7.249 mg/kg in olive oils.

The molecules identified by the chemical screening of the samples are different from those found by [7], who identified a total of 25 chemical molecules in cottonseed oils. This could be explained by the difference in the solvent used to extract the molecules. The 07 molecules identified in cottonseed oil samples are of varying health interest in terms of their properties. According to [2], cottonseed oil acts as an anti-inflammatory, anticancer, anti-allergic, and antioxidant. Its cardio-protective properties help reduce the risk of various diseases.

The choice of the different parameters (measurements) is linked to the method of extraction of cottonseed oil, which is exclusively mechanical in the different industrial zones of the country, and also the application of chemical refining. Hence, there is an interest in the analysis of these different parameters in order to ensure the sanitary quality of cottonseed oils.

4. Conclusion

The aim of this study was to assess the safety of refined cottonseed oils produced in Burkina Faso. The analyses revealed that cottonseed oils were free from chemical contaminants likely to affect consumer health, such as pesticides, heavy metals (e.g., lead and cadmium), and gossypol (a toxic pigment found in cottonseed). The absence of these contaminants in the oils proves not only the efficiency of the technology used in the oil refining process, but also demonstrates the suitability of the equipment employed. However, the study reveals that the quality indices of the oils, especially the peroxide value, show values above the permitted limits. In order to improve the quality of the finished product, cottonseed crushing plants should procure better-quality raw materials. This study has therefore not only helped to dispel doubts about the quality of refined cottonseed oils produced in the country but may also reassure the authorities in their efforts to support the industry and edible oil quality control structures. Looking ahead, a study on the quantification of molecules of health interest in cottonseed oil would be necessary.

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Data Availability Statement

The data used to support the findings of this study are available upon request from

the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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