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Research Article

Nutritional Evaluation of Avocado Fruit for Produce Functional Foods

Salem M.A.[1], Alaa A. Alghanam[1], and Sahar R. Abd El-Hady[2]

[1] Food Sci. and Tech. Dept., Fac. of Agric. Tanta Univ., Egypt.

[2]Food Sci. and Technology Dept., Fac. of Argic., Kafrelsheikh Univ., Egypt.

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Abstract:

The study aimed to evaluate the nutritional and phytochemical properties of Avocado fruit and explore the possibility of using Avocado puree as a fat replacer in muffins to create functional foods rich in phytochemical compounds. The results showed that Avocado fruit has a high crude fat content of 15.80%, primarily composed of monounsaturated fatty acids (MUFA). The ash content was low at 1.20%, while the crude fiber content was relatively high at 6.80%. Avocado fruit is also notable for its mineral content, with high levels of potassium (495.0 mg/100g) and moderate levels of phosphorus (58.0 mg/100g), magnesium (30.0 mg/100g), and calcium (13.20 mg/100g). Additionally, Avocado fruit is a good source of various vitamins. The predominant phenolic compound in Avocado fruit flesh was chlorogenic acid (17.38%). Avocado fruit oil is known for its high content of monounsaturated fatty acids, particularly oleic acid (C18:1), which makes up the majority of the fatty acids in avocado oil at 50.85%. Avocado oil also contains significant amounts of palmitic acid (C16:0) at 28.06% and linoleic acid (C18:2) at 12.87%. The study found that the addition of Avocado puree as a fat replacer in muffins did not have a significant effect on the sensory characteristics of the prepared muffins, even at 100% replacement levels. Based on these results, the study suggests that muffins containing Avocado puree as a fat replacer can be developed as functional foods.

1. Introduction

Avocado is one of the most important crops in the tropical and subtropical countries of the world and is highly productive and cultivated in areas such as Central America, East Africa, West Africa, and Nigeria. (Indriyani et al., 2016). The Avocado (Persea Americana Mill.) is from the Lauraceae family (Krumreich et al., 2018). It has a yellow-green-to-purple skin and is described as a berry with a thick, fleshy mesocarp surrounding a single large seed. The fruit weighs about 50 to 1 kilogram, with the edible flesh (mesocarp) contributing 50–80% of its total weight, while the seed makes up 10 to 25% (Pahua-Ramos, 2014).

According to the FAO (2022), the global production of avocado fruits exceeded 8.05 million metric tons in 2020.The production and consumption of avocados have expanded drastically in the past 150 years because these fruits are highly valued for their high variety of vital compounds, especially phenolic compounds (Ong, et al 2022).

It's mainly consumed as fresh fruit for its good nutritional value (Hurtado-Fernandez et al., 2018). Avocado is a major market worldwide, alongside its use in the cosmetics, edible oil, and food processing industries (Indriyani et al., 2016). The pulp of this fruit contains about 60% oil, 7% skin, and approximately 2% seed (Tan et al.,2017). Avocado fruits are superfoods, rich in nutrients and phytochemicals (Comerford et al., 2016). As well as Minerals such as Iron, Magnesium, Phosphorus, and Potassium (Goff and Klee, 2006).

The avocado fruit contained relatively high amounts of oil in comparison with other vegetable oils, like pumpkin seed oil (Boujemaa et al., 2020) or cactus oil (Gharby et al., 2020). Compared to other sources of vegetable oil, the major fatty acid of avocado oil is oleic and linoleic acid. Oleic acid is supposed to exhibit modulatory effects in extensive physiological functions (Sales-Campos et al., 2013).

Avocado is also rich in unsaponifiable compounds such as sterols, mainly b-sitosterol, vitamins, carotenoids, tocopherols, and the phenolic compounds are of significant interest for their antioxidant and anti-inflammatory properties (Kosińska et al., 2012 and Zhang et al., 2013) Cupcakes are popular bakery products, consumed for breakfast or as an afternoon snack in many countries. They are sweet baked goods made from a thick batter that typically includes flour, sugar, shortening, milk, salt, eggs, and a rising agent like baking powder (Stevenson, 2003). Cupcakes are known for their good taste, soft texture, and spongy structure, which gives them a high volume (Schatzel, 2018). The effect of adding avocado puree on the physical and microstructure of butter cake, the cellular structure of the crumb exhibited a decrease in the number of air cells, while the average cell size increased with the addition of avocado puree, studied by (Marina, 2016). Another study, by Abdul Manaf (2017), confirmed the feasibility of using avocado puree as a fat replacer in muffins. The study found that incorporating higher amounts of avocado led to the formation of a poor protein matrix in the muffin crumb. So, this paper aims to study the nutritional evaluation of avocados and make unconventional products from avocados to take advantage of their high nutritional value, high-fat content, and antioxidant activity including bakery products such as muffins.

2. Materials and Methods

2.1. Preparation of avocado puree

Soft-ripened fresh avocado fruit with accurately washed tap water. The flesh of the avocado was scooped out and homogenized in blender Model (BRAUN) type (4148), according to (Abdul Manafa et al., 2017). Finally, the prepared puree was added to processed products namely (muffin).

2.2. Preparation of muffin

Control muffin samples were prepared of ingredients, with wheat flour (72% Extra.) (200.0g), sugar (80.0g), salt (1.0 g), skimmed milk powder (160.0g) Shortening (100.0g), fresh whole egg (60.0g), baking powder (12.0 g) and vanilla (2.00g) according to the method described by (Abdul Manafa et al., 2017). Avocado puree was used as a fat replacer (50 and 100%) in preparing muffins. All Different muffin formulas were baked at 180° C for 25-30 min then cooled on racks for about one hour before evaluation, packaged in polyethylene bags, and stored at fridge temperature 5oC according to AACC (2005).

2.3. Analytical methods

2.3.1. Chemical composition and mineral contents

AOAC methods (2010) were used to determine moisture, ether extract, crude protein, ash content, crude fiber, total sugar, and total carbohydrate content were calculated by difference. Samples were prepared for mineral determination according to the AOAC method (2010). Total phosphorus was determined colorimetrically using the ascorbic acid method as described by Murphy and Riley (1962).

The potassium and sodium were estimated using a flame photometer as given by Pearson (1976). Calcium, iron, magnesium, selenium, and zinc samples were conducted using the atomic absorption spectrophotometer Perken Elmer Model 20180 following the method of Pearson (1976).

Determinations of vitamin B1 (thiamine), B3 (niacin) pantothenic acid (B5), pyridoxine (B6), folic acid (B9), and Phytonadione (K) were performed by acid and enzymatic hydrolysis, and separated with different HPLC columns, in the appropriate mobile phases, and detections were performed at the respective wavelengths according to AOAC, (2010).

Vitamin C (ascorbic acid) content of avocado fruits was determined using the method of AOAC (2010).

2.4. Determination of bioactive compounds

2.4.1. Total phenolic, total flavonoid compounds, and antioxidant activity*:*

Total phenolic compounds were extracted according to the method described by Salem et al. (2018). Total phenolic compounds of the extracts were determined spectrophotometrically using the Folin-Ciocalteau reagent and a gallic acid standard curve. The total flavonoid of the avocado extract was determined by the method of Djeridane et al. (2006). While total antioxidant activity (DDPH method) was performed as described by Lim and Quah (2007).

2.5 Fractionation and identification of phenolic and flavonoid compounds of avocado fruits:

"In this study, phenolic and flavonoid compounds in avocado fruits were separated and identified using HPLC analysis at the Food Technology Research Institute, El-Giza Governorate, Egypt.The methods employed for this analysis were based on previous research by Evangelisti et al. (1997) for phenolic compounds and Mattila et al. (2000) for flavonoid compounds."

2.6. Fatty acids composition of avocado fruit oils

The methyl esters were prepared using benzene, methanol, and concentrated sulfuric acid (10:86:4), and the methylation process was carried out for one hour at 80-90 oC according to Stahl (1967). Identification of the fatty acid methyl esters was performed by G.L.C. using a spectophysic integrator (AOAC., 2010).

2.7. Color evaluation of muffins

The surface color of muffin samples was determined by the tristimulus color system using a spectrophotometer (MOM, 100D, Hungary). Color coordinates X, Y, and Z were converted to corresponding Hunter L*, a*, and b* color coordinates according to the formula described by Francis (1983).

Sensory evaluation of muffins

A semi-trained panel of twenty members used ten-point hedonic-scale ratings for color, taste, odor, texture, and overall acceptability in order to provide organoleptic characteristics for different repaired biscuits, Watts et al. (1989). Liked extremely 9, liked very much 8, liked moderately 7, liked slightly 6, neither liked nor disliked 5, disliked slightly 4, disliked moderately 3, disliked very much 2 and disliked extremely 1.

2.8. Statistical analysis

Data was analyzed using a one-way analysis of variance (ANOVA) to show the significance between treatments. The statistical software SPSS (Version 17.0, SPSS Inc., Chicago, IL) was used for analysis (Steel and Torrie,1980).

3. Results and Discussion

A. Chemical composition and mineral content of Avocado fruit

The approximate chemical composition and mineral contents of Avocado fruit are given in Table (1). The obtained results found that the moisture content of avocado fruit is high, at 78.62%, while the crude protein content is relatively low, at 2.50%. The crude fat content is high, at 15.80%, which is mostly composed of monounsaturated fatty acids (MUFA). The ash content is low, at 1.20%, while the crude fiber content is relatively high, at 6.80%. The total sugar content is low, at

0.80%, while the total carbohydrate content is moderate, at 9.10%.

Table (1): Chemical composition (%), Mineral (mg/100g on dw), and Vitamin (mg/100g on dw) content of Avocado fruit.

Chemical composition	Avocado fruit (%)	Minerals content	Avocado fruit (mg /100g)	Vitamins	Avocado fruit (mg /100g)
Moisture	78.62	Sodium (Na)	5.80	thiamine (B1)	0.08
Crude protein	2.50	Potassium (K)	495.0	niacin (B3)	0.185
Crude Fat	15..80	Magnesium(Mg)	30.0	Pantothenic acid (B5)	0.10
Ash	1.20	Phosphorus (P)	58.0	pyridoxine (B6)	0.30
crude fiber	6.80	Calcium (Ca)	13.20	folic acid (B9)	87.0
Total sugar	0.80	Iron (Fe)	0.40	ascorbic acid (C)	11.90
Total carbohydrates	9.10	Copper (Cu)	0.14	Phytonadione (K)	1.30
-	-	Zinc (Zn)	0.67	-	-

Each value was an average of three determinations

These results are in accordance with (Mooz, 2012; Vinha et al., 2013; Nwaokobia, 2018; Bhuyan, 2019; and Abass et al., 2020), who reported that the chemical results of avocado fruit were 67 to 78% moisture, 13.5 to 24% lipids, 0.8 to 4.8% carbohydrate, 1.0 to 3.0% protein, 0.8 to 1.5% ash, and 1.4 to 3.0% fiber.

From the same table, it could be noticed that the mineral content of avocado is particularly noteworthy, with high levels of potassium at 495.0 mg/100g and moderate levels of phosphorus at 58.0 mg/100g, magnesium at 30.0 mg/100g, and calcium at 13.20 mg/100g. The sodium content is relatively low, at 5.80 mg/100g. Avocado also contains moderate levels of iron (0.40 mg/100 g), selenium (0.40 mg/100 g), copper (0.14 mg/100 g), and zinc (0.67 mg/100 g). These results are in accordance with those (Bhuyan, 2019; Abass et al., 2020) who found that the mineral content of avocados includes sodium (8 mg/100g), potassium (507 mg/100g), calcium (13 mg/100g), magnesium (29 mg/100g), iron (0.61 mg/100g), zinc (0.68 mg/100 g), and phosphorus (54 mg/100g). According to the same table, avocado fruit is a good source of various vitamins. The amount of each vitamin per 100g of avocado fruit is as follows: pantothenic acid (B5) 0.10 mg per 100g, thiamine (B1) 0.08 mg per 100g, niacin (B3) 0.185 mg per 100g, pyridoxine (B6) 0.30 mg per 100g, Vitamin (K) 1.30 mg per 100g, ascorbic acid (C) 11.90 mg per 100g, folic acid (B9) 87.0 mg per 100g. The obtained data differed from those reported by Ranade and Thiagarajan (2015). In addition, Nguyen et al. (2022) reported that some differences observed in avocado fruit may be attributed to plant variety, soil structure, environmental conditions, ripeness stage, harvest time, and post-harvest handling could contribute to this variation of Avocado fruit.

B. Bioactive compounds of Avocado fruit:

Data in Table (2) shows that the antioxidant activity of Avocado fruit was recorded at 91.01% , while total phenolics and total flavonoids were at 20.048 and 18.10% , respectively. These results are in accordance with Shehata and Soltan (2013), Abass et al. (2020) and Nguyen et al. (2022).

Table (2): Bioactive compounds in the Avocado fruit.

Sample	Bioactive compounds		
	Total phenolics (mg/g)	Total flavonoids (mg/g)	Antioxidant activity(DPPH %)
Avocado fruit	20.048	18.10	91.01

Each value was an average of three determinations.

C. Flavonoid fractions of avocado fruit:

High-performance liquid chromatography (HPLC) was used for qualitative and quantitative analysis of flavonoid compounds in flesh avocado fruit, as represented in Table (3). Seventeen flavonoid compounds were detected in authentic samples.

It could be noted that the predominant flavonoid compound in avocado was quercetin-3-O-glucoside, which was the predominant identified compound in flesh avocado fruit (23.40%). The second predominant one in flesh avocado fruit was quercetin 3-O-galactoside (16.04%), followed by quercetin-3-0-arabinosyl-glucoside (13.25%), quercetin derivative (III) (10.35%), quercetin-diglucoside rutin (10.18%), quercetin derivative (1) (8.92%), quercetin-3,4'-diglucoside (7.35%), quercetin-3-0-arabinoside (4.98%), quercetin 3-0-rutinoside (3.83%), quercetin-dihexoside (0.32) , querectin-glucoronide (0.25%) , quercetin-pentoside-hexoside (0.22%) , quercetin-hexoside (0.21%) , querectin-rhamnoside-hexoside (0.19), and isorhamerin-glucuronide (0.15%). The obtained data differ from those reported by Shehata and Sultan (2013) who found that the fractions of avocado contained the predominant flavonoids rutin, rosmarinic, quercitrinic, quercitin, hesperetin, and kampferol with concentrations of 82.03, 60.71, 87.40, 222.24, 176.52, and 60.77 ppm, respectively.

Table (3): Flavonoid fractions of avocado fruit.

Flavonoid Compounds	Contents (%)
quercetin-3,4'-diglucoside	7.35
quercetin 3-0-rutinoside	3.83%
quercetin-3-0-arabinosyl-glucoside	13.25
quercetin 3-O-galactoside	16.04%
quercetin-3-0-arabinoside	4.98%
quercetin-3-O-glucoside	23.40%
quercetin derivative (1)	8.92%
quercetin derivative (II)	0.18 %
quercetin derivative (III)	10.35%
quercetin-diglucoside rutin	10.18 %
quercetin-dihexoside	0.32
quercetin-pentoside-hexoside	0.22 %
querectin-glucoronide	0.25%
quercetin-hexoside	0.21%
querectin-rhamnoside-hexoside	0.19
quercetin-rhamnoside-pentoside	0.18%
isorhamerin-glucuronide	0.15%
Total flavonoids	100.0

D. Phenolic compounds fractions of avocado fruit:

Results of high-performance liquid chromatography (HPLC) in Table (4) show the phenolic compounds in avocado fruit and note that chlorogenic was the predominantly identified compound in flesh avocado fruit (17.38%). The second predominant one in flesh avocado fruit was Catecheia (16.39%), followed by

Oleuropin (12.06), Benzole (12.04%), Ellagie (10.46), Gallic (9.54), Ferulic (7.74), Caffeine (4.65), Caffeine (4.65),4-amino-benzoic (3.42), Coumarin (2.18), Salicylic (1.64), Catechol (1.35), and Pyrogallol (0.26). The obtained data differed from those reported by Shehata and Sultan (2013) who found that the fractions of avocado contained the predominant phenols pyrogallol, ellagic acid catechin, protocatechuic acid, catechol, vanillic acid, ferulic acid, and coumarin with concentrations of 217.57, 73.41, 47.78, 23.34, 21.36, 3.88, 2.06, and 0.99 ppm, respectively.

Table (4): phenolic compound fractions of avocado fruit.

Phenolic Compounds	Contents (%)
Gallic	9.54
Pyrogallol	0.26
3-OH-Tyrosol	0.89
Catechol	1.35
4-amino-benzoic	3.42
Catecheia	16.39
Chlorogenic	17.38
Benzole	12.04
Caffeine	4.65
Ferulic	7.74
Ellagie	10.46
Salicylic	1.64
Oleuropin	12.06
Coumarin	2.18
Total phenols	100.0

E. Fatty acid composition of avocado fruit:

The table (5) shows the fatty acid composition of avocado fruit oil. Avocado fruit oil is known for its high content of monounsaturated fatty acids, particularly oleic acid (C18:1), which makes up the majority of the fatty acids in avocado oil at 50.85%. Oleic acid is considered a healthy fat and is associated with various health benefits. Avocado oil also contains significant amounts of palmitic acid (C16:0) at 28.06% and linoleic acid (C18:2) at 12.87%. Palmitic acid is a saturated fatty acid, while linoleic acid is a polyunsaturated fatty acid. Both of these fatty acids are commonly found in plant-based oils. The remaining fatty acids, including myristic acid (C14:0), palmitoleic acid (C16:1), stearic acid (C18:0), and linolenic acid (C18:3), are present in relatively small amounts in avocado oil.

The total saturated fatty acid (TSFA) concentration is 29.04%, while the total unsaturated fatty acid (TUSFA) concentration is 70.96%. The main fatty acids in avocado oil are oleic and palmitic acids (Flores et al., 2019; Nasri et al., 2021 and Ranade and Thiagarajan, 2015). It's worth noting that the fatty acid composition of avocado oil can vary depending on factors such as the avocado variety and growing conditions. However, the composition provided gives a general idea of the fatty acid profile of avocado fruit oil. Flores et al. (2019).

Table (5): Fatty acid composition (%) of avocado fruit oil.

Fatty acid (FA)	Contents (%)
Myristic Acid C14:0	0.18
Palmitic Acid C16:0	28.06
Palmitoleic Acid C16:1	5.66
Stearic Acid C18:0	0.80
Oliec Acid C18:1 n9	50.85
Linoleic Acid C18:2 n6	12.87
Linolenic AcidC18:3 n3	1.58
Total saturated fatty Acids (TSFA)	29.04
Total unsaturated fatty Acids (TUSFA)	70.96
Monounsaturated fatty Acids (MUSFA)	56.51
Polyunsaturated fatty Acids (PUSFA)	14.45

F. Color Characteristics of muffin made with avocado puree:

Color is an important trait because it can stimulate an individual's appetite. As presented in Table (6). shows the color attributes of a muffin made with avocado puree as a fat replacer. The color attributes are measured using the L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) parameters. Significant differences ($p < 0.05$) in color measurements were reported. The control sample (F0) is made with 100% fat, while F1 and F2 are made with 50% and 100% avocado puree, respectively. The results show that the muffin made with 50% avocado puree (F1) has a significantly higher L* value (lightness) and a significantly lower a* value (redness/greenness) compared to the control sample (F0) while . muffin made with 100% avocado puree (F2) Similar to control sample. The b* value (yellowness/blueness) is significantly different between F0 and F1.

On the other hand, the muffin made with 100% avocado puree (F2) has a significantly lower L value (lightness) and a significantly higher b value (yellowness/blueness) compared to the control sample (F0). This means that the muffins made with 100% avocado puree are darker in color and more yellow. The A value (redness/greenness) is not significantly different between F0 and F2. Based on the table, it can be concluded that incorporating avocado puree as a fat replacer in muffins can affect their color attributes. The muffins with 50% avocado puree showed a lighter and greener color, while the muffins with 100% avocado puree had a color similar to the control sample. It seems that the color variation of the muffins could be attributed to the pigments present in avocado puree, specifically carotenoids (such as lutein) and chlorophyll. (Ashton et al., 2006 Nurul Ain et al., 2016). Additionally, natural enzymatic browning, which forms brown pigments of polymerized quinones in the avocado flesh, may also contribute to the dark color of avocado-treated muffin samples. (Gomez-Lopez, 2002). It is mentioned that the Maillard reaction and caramelization do not occur since the crumb part of the muffins does not reach 100°C. Therefore, the color of the crumb is likely the result of the ingredients used and their interaction during baking. According to Al-Sayed and Ahmed (2013).

Table (6): Color attributes of muffins made with avocado puree.

Parameters / Samples	L* (Lightness)	a* (Redness/greenness)	b* (Yellowness/blueness)
F0	48.92±4.97b	21.95±1.00a	37.78±2.24b
F1	62.43±1.90a	14.74±1.42b	40.13±0.69a
F2	48.90±0.74b	22.44±0.33a	41.72±2.27a

Each value was an average of three determinations ± standard division.

Values followed by the same letter in columns are not significantly different at $p \leq 0.05$.

F0: Control muffin with 100% fat; F1: 50% Avocado puree (as fat replacer): F2: 100% Avocado puree (as fat replacer)

G. Sensory characteristics of muffins made with avocado puree:

Table (7) shows the sensory characteristics of a muffin made with avocado puree as a fat replacer. The muffins were evaluated based on color, taste, odor, texture, appearance, and overall acceptability. The control sample (F0) had the highest overall acceptability score of 9.79, while the muffin made with 50% avocado puree (F1) had the lowest overall acceptability score of 7.99.

The muffin made with 100% avocado puree (F2) had an overall acceptability score of 8.53, higher than F1 but lower than F0. Overall, the results suggest that incorporating avocado puree as a fat replacer in muffins can still result in acceptable sensory characteristics, although there may be slight differences compared to the control sample. The present results agree with Abass et al. (2020).

Table (7): Sensory characteristics of muffins made with avocado puree.

Parameters / Samples	Color	Taste	Odor	Texture	appearance	Overall Acceptability
F0	8.50±0.50a	9.16±0.28a	8.83±0.76a	8.66±0.57a	8.83±0.73a	9.79±0.73a
F1	8.16±0.75a	8.00±0.50b	7.83±0.29a	8.00±0.50a	8.16±0.27a	7.99±0.27a
F2	8.33±0.29a	8.66±0.29ab	8.66±.58a	8.50±0.50a	8.10±0.17a	8.53±0.17a

Each value was an average of twenty determinations ± standard division.

Values followed by the same letter in columns are not significantly different at $p \leq 0.05$.

F0: Control muffin with 100% fat; F1: 50% Avocado puree (as fat replacer): F2: 100% Avocado puree (as fat replacer)

Conclusions

From this study, it can be concluded that, Avocado puree can be used as a natural ingredient to replace butter in bakery products, such as muffins, to obtain nutritious and sensory products. Avocados are a rich source of nutrients, and phytochemicals.

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