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Effect of Oat and Chia Flours Biscuit on Rats Fed on High Fat Diets

Abu Raya, M. A.[1]; Jihan A. A. Ghoneim[1]; A. M. M. Elanany[2] and A. M. Awad[1*]

[1]Food Industries,Food Industries Department,Faculty of Agriculture, Mansoura University
[2]Department of Special Food & Nutrition, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt

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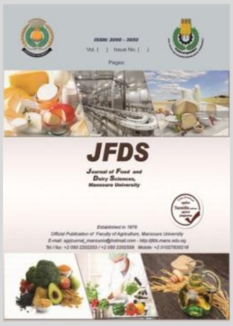

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ABATEACT

The research was conducted to study the effect of replacing wheat flour used in biscuit manufacturing with flour from both oats and chia seeds in different proportions on the chemical composition of the produced biscuits compared to the control sample The results showed an increase in protein and fiber content with an increase in the proportion of oat flour and chia seeds added to the biscuits The results of sensory and physical tests indicated that the control sample recorded the highest values in size characteristics compared to the samples made with the addition of oat and chia flour where the replacement rate reached Nutritious biscuits can be prepared by replacing wheat flour up to 15% with oat or chia flour without negative effects on the acceptance of the and the biological results indicated that feeding on diets containing higher levels of oat and chia flour at higher levels there was a decrease in the body weight of the mice compared to the control group as a decrease in triglyceride levels total cholesterol harmful cholesterol and low-density lipoprotein cholesterol was observed in the groups of mice that were fed high-fat biscuits which were substituted with oatmeal and chia seeds compared to the mice that were fed the high-fat basic diet The study recommends adding oatmeal and chia seeds along with wheat flour in meal preparations to reduce body weight and improve health status.

Keywords: oatmeal - chia seed flour - chemical and physical properties - sensory properties - biological evaluation.

INTRODUCTION

The overconsumption of high-fat, calorie-dense, and highly processed foods with rapid absorbability may contribute to systemic inflammation and the development of a spectrum of cardio-metabolic disorders, like obesity, insulin resistance, and glucose intolerance (Alissa and Ferns, 2014).

According to factors elevate the risk of chronic conditions , including diabetes and cardiovascular disorders. Consequently, there is increasing interest in exploring new curative strategies, like nutraceutical foods , for the prevention of chronic diseases and managing it with the associated health risks (Creus *et al.,* 2016). Conventional functional foods are characterized by the presence of bioactive compounds like dietary fiber, polyunsaturated fatty acids, phytochemicals, and antioxidants which play a significant role in mitigating the chronic diseases risks (Gazem and Chandrashekariah, 2016).

Clinical evidence indicates that dietary fiber intake confers cardiovascular benefits for at-risk populations. A study by Xu *et al.* (2021) showed that oat β-glucan supplementation significantly reduced serum total cholesterol by 8.41% and low-density lipoprotein cholesterol (LDL-C) by 13.93% in hypercholesterolemic individuals (Xu *et al.,* 2021). Epidemiological evidence consistently indicates an inverse association between dietary fiber consumption and cardiovascular disease risk, including ischemic heart disease (Crowe *et al*., 2012) and diabetes (type 2) mellitus (Cho *et al.,* 2013). A separate meta-analysis further substantiated that each incremental 7 g/day increase in total dietary fiber consumption It is connected with a 9% lower risk of cardiovascular disease (Threapleton *et al.,* 2013).

The demand from consumers for foods that promote health, especially those high in dietary fiber, has increased dramatically. This trend has prompted food manufacturers to enhance the fiber content of products as a potential strategy for mitigating various health concerns, including hypertension, diabetes mellitus, colorectal cancer, and related metabolic disorders. The intake of dietary fiber-rich compounds, including cellulose, hemicellulose, lignin, and gum, confers multiple physiological benefits and plays a significant role in promoting human health (Sudha *et al*., 2007). Incorporating whole grains or composite flours derived from wheat, legumes, and cereals in biscuit formulation enhances both functional characteristic nutritional quality f the final product (Vitali *et al*., 2009).

Biscuits constitute a category of bakery products recognized for their versatility as snack foods, characterized by prolonged shelf stability, convenience, and diverse sensory attributes. Their formulation adaptability allows for incorporation into various dietary patterns (Arepally, 2020). Biscuits can be formulated with diverse functional ingredients possessing enhanced nutritional value, serving as an effective vehicle for dietary enrichment. Their fortification with non-conventional components—particularly fiber, vitamins, and minerals—offers a viable strategy to address micronutrient deficiencies and improve overall dietary quality (Čukelj, 2016).

Oat biscuits constitute a nutritionally fortified biscuit variant, valued for their enhanced bioactive profile and favorable textural and organoleptic properties imparted by oat constituents. Oats represent a nutritionally dense cereal grain, characterized by high-quality carbohydrates and proteins with a favorable amino acid profile. Additionally, they contain significant lipid content, predominantly unsaturated fatty acids, along with essential minerals, vitamins, and bioactive

* **Corresponding author.**
E-mail address: shaark44@gmail.com
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phytochemical compounds (Alok, 2015). Oats contain soluble fiber in the form of β-glucans, which have been clinically demonstrated to reduce serum cholesterol levels (Gunness, 2017).

Oats (*Avena sativa*) have a well-balanced nutritional profile. This grain serves as a nutritionally valuable source of complex carbohydrates and high-quality protein, characterized by a favorable amino acid profile. Oats contain substantial quantities of lipids, predominantly unsaturated fatty acids, along with essential minerals, vitamins, and bioactive phytochemical compounds. The most nutritionally significant of oat flour characteristic is its elevated fiber content, particularly β-glucan, which exhibits cholesterol-lowering effects through enhanced bile acid excretion. Oats demonstrate multiple physiological benefits, including hypocholesterolemia and potential anticancer properties. Furthermore, oats have recently gained approval for incorporation in gluten-free diets for celiac patients. Numerous studies support the utilization of oat flour as a functional ingredient in baked goods, (bread and biscuits), because of its high dietary fiber content (El-Qatey *et al*., 2018).

Chia seeds which knows as (*Salvia hispanica L.*) are oilseeds classified owing to their substantial lipid component (25-40% of total composition). They are one of the richest botanical sources of α-linolenic acid (ALA), with concentrations reaching 68% of total fatty acids - significantly higher than flaxseed (57%), the most commonly utilized alternative (Ayerza and Coates, 2011). Additionally, chia seeds contain numerous bioactive constituents, including: (1) phenolic antioxidants like chlorogenic acid, myricetin , quercetin, caffeic acid, and, gluten-free proteins with a complete essential amino acid profile, dietary fibers and essential minerals (Costantini *et al.,* 2014). According to nutritional study, chia seeds provide 30-34 g of total dietary fiber per 100 g sample, of which 85-93% is insoluble fiber and the remaining 7-15% is soluble fiber (Kulczynski *et al.,* 2019). Consequently, this quantity satisfies the dietary recommended daily intake of fiber for adults, which ranges between 25–35 g/day according to established nutritional guidelines (Munoz *et al.,* 2013).

According to the above, The goal of the study was to increase the biscuit's nutritional value and investigate how adding varying amounts of oat or chia flour affected the prepared biscuit's chemical makeup, physical characteristics, and sensory appeal.

MATERIALS AND METHODS

Materials:

Oats and chia were bought from the Agricultural Research Center, Ministry of Agriculture, Giza, Egypt.

Flour, salt, oil, baking powder, butter and sugar were bought from Giza, Local market, Egypt.

Rats were bought from the Experimental Animal House, Food Technology Research Institute, Agricultural Research Center, Ministry of Agriculture, Giza, Egypt.

Chemicals: Folin-Ciocalteu's phenol reagent (2N), Sodium Carbonate (99.8%) (NaCO3), sodium nitrite (NaNO2), Aluminum chloride (Alcl3), sodium hydroxide (NaOH) and 2, 2-Diphenyl-1-picryhydrazyl (DPPH) were purchased from Sigma-Aldrich (St. Louis, Mo, USA). The kits have been purchased from Gamma-Tread Company, Cairo, Egypt.

Methods:

Chemical Analysis:

AOAC (2000) methodologies were used to determine the approximate moisture, fat, crude protein, ash, and crude fiber analysis. The calculation of carbohydrates was calculated using difference.

Carbohydrates % =

100 – (% moisture + % protein + % fat + % ash + % fiber)

Caloric value of the products was calculated using the appropriate factor as described by (FAO/WHO/UNU, 1985). As following equation:

Energy value (Kcal) =

[(carbohydrates x 4.0) + (fat x 9.0) + (protein x 4.0)] .

Determination of minerals:

Mineral contents iron (Fe), zinc (Zn), calcium (Ca), potassium (K), sodium (Na) and Phosphor (P) in samples were digested by using a pye Unicum SP 1900 Atomic Absorption Spectroscopy instrument (Perkin Elmer model 4100 ZL) as described by the AOAC, (2000), at Soils, Water and Environment Research Institute (SWERI), ARC, Giza, Egypt.

Total phenols, total flavonoids and antioxidant activity determination:

Total phenol content was estimated based on procedures described by (Batista *et al.,* 2011).

Total flavonoids were determined using the method described by (Batista *et al.,* 2011). The electron donation ability of the obtained ethanol extracts was measured by 2, 2-diphenyl-1-picrylhdrazyl radical (DPPH) according to the method of (Hanato *et al.,* 1988).

Technology part (Application part):

Preparation of Biscuits:

The ingredients of s consisted of 100 g of wheat flour (72% extraction), 33 g of fat (butter), 36 g of sugar, 3 g of baking powder, 0.25g of vanillin, and 25 ml of milk. Fat (butter), sugar and vanillin has been mixed in a dough mixer using the flat beater for 1 min. then scraped down and continued to mix for 3 min. at high speed. Wheat flour and baking powder were added to mixture and mixed at low speed, then it was sheeted to 3mm thickness. Circles cut of paste pieces were done by using of templates with an outer diameter of 60mm. The biscuits baked at 170 to 180 ˚C for 12 min. Preparation method followed the procedure described by Wade (1988). After baking, leave them to cool at room temperature before sealing them in polyethylene bags to prevent moisture loss and then storing them at room temperature (20±2˚C).

Texture analysis of biscuits:

Biscuit prepared by adding oat and chia seed powder with different substitution ratios were screened and their properties were for texture profile (TP) were evaluated using a Brookfield CT3 instrument (Brookfield Engineering Laboratories, Inc., MA 02346-1031, USA) using a TA-JTPB AACC-compatible probe, (AACC, 2000), in which a sample of biscuit, about 2 mm thick, was placed under a three-point bender and a TA7 blade has been used to assemble the mass probe and the following characteristics were determined: Hardness (N) (average of cycle 1 and cycle 2), adhesiveness (MJ), cohesiveness, gumminess (N) and chewiness (MJ).

Physical characteristic of biscuits:

The physical characteristic of the biscuits has been measured after cooling. The volume of biscuits was measured in cm^3 by rapeseed displacement. Specific volume (cm^3/ g) was calculated by dividing the volume (in cm^3) by the weight (in g) according to the method by AACC (2000).

Sensory evaluation:

The biscuits has been evaluated for their sensory characteristic (taste, color, texture, odor, crust appearance and over all acceptability) by ten members of the staff of the Bread and Pastry Technology Research Department at the Food Technology Research Institute, Agriculture Research Center. The scoring system was established according to the method by the A.A.C.C. (2000).

Biological evaluation:

Ethics approval and consent to participate:

The experimental procedures involving animals in this study were conducted in accordance with the guidelines established by the National Institutes of Health (NIH) for the care and use of laboratory animals (NIH Publication No. 8023, revised 1978 and updated 2011), with approval obtained from the relevant institutional authorities. All animal experimentation was conducted in full compliance with applicable national and regional regulations governing the care and use of laboratory animals, including (specific guidelines/laws) [Arrival guideline.2.0 updated in July 2020].

Biological assay:

Adult male white mice (50 mice) with an average weight of (180±10 g) (8 weeks) were obtained and housed in the experimental house, Food Tech. Res. Inst. Agri. Res. Center, Giza, Egypt. The mice were individually housed in polypropylene cages with a 12 hour light /dark cycle. The temperature and relative humidity of a room are set at (25 ± 2˚C) and 60-65%, respectively. Rats were fed on basal diet and tap water for one week as an adaptation period as reported by **(Reeves *et al.,* 1993)**.

Experimental Design:

After the adaptation period (one week), the rats were randomly divided as follows: Group (1) was fed on basal diet as a (negative control) (Jayasekhar *et al*., 1997). The groups (G2 to G10) has been fed on the hyperlipidemia diet for ten days, and then divided as follow until the end of experimental period.

- The first group is fed the basic diet (negative control).
- The second group is fed a basal diet rich in fat content (positive control).
- The third group is fed a high-fat basal diet +10% oats.
- The fourth group fed on the basal diet rich in fat + oats by 20% oats.
- The fifth group is fed with a high percentage of fat + 10% chia.
- The sixth group is fed the basic diet rich in fat + 20% chia.
- The seventh group feeds on the basic diet that consists of a high percentage of fat + biscuits containing 10% oats.
- The eighth group feeds on the basic diet that consists of a high percentage of fat in addition to biscuits containing 20 % oats.
- The ninth group feeds on the basic diet that consists of a high percentage of fat in addition to biscuits containing 10 % chia.
- The tenth group feeds on the basic diet that consists of a high percentage of fat in addition to biscuits containing 20 % chia.

Biological evaluation:

The experimental period spanned 8 weeks, during which daily feed consumption was monitored and weekly body weight measurements were recorded for all rats. Cumulative body weight gain and total feed intake were determined for the study duration. Feed efficiency ratio was subsequently calculated using the following formula:

BWG % =

(Final Weight – Initial Weight) / Initial Weight × 100

Liver, kidney weighed then stored in formalin solution 10% it was calculating the absolute and relative organ weight. Relative organ weight (liver, kidney and heart) was calculation as following formula:

Relative organ weight =

{organ weight / final body weight} × 100

Collection the blood samples:

Upon completion of the experimental period, rats were fasted overnight, anesthetized using diethyl ether, and euthanized. Blood samples were collected via the ocular plexus and transferred into dry, clean glass centrifuge tubes to prevent coagulation. The samples were allowed to clot for 15 minutes at refrigeration temperature before centrifugation at 3000 rpm for 15 minutes. The resulting serum supernatant was carefully separated and stored at -20°C until further biochemical analysis.

Biological parameters assay:

Triglyceride was determined in serum using the method by Fassati, P. and prencipe, L. (1982).

Cholesterol was calorimetrically determined according to the enzymatic method of Rifai *et al.,* (1999).

High-density lipoprotein cholesterol [HDL-C] was determined using the method by Lipez-Virella *et al.,* (1977).

Very low-density lipoprotein cholesterol [VLDL-C] was calculated by Lee and Nieman, (1996).

$$\textbf{VLDL-C (mg/dL)} = \frac{\textbf{Triglycerides}}{5}$$

Low density lipoprotein cholesterol [LDL-C] (Lee and Nieman, 1996).

LDL-C [mg/dL] = TC – [VLDL + HDL]

Serum aspartate aminotransferase [AST] activity was calorimetrically measured according to the method by Reitman and Frankel, (1957).

Alanine aminotransferase [ALT] of serum activity was calorimetrically measured according to Reitman and Frankel, (1957). Serum alkaline phosphatase [ALP] (Bessay *et al.,* 1946). Serum uric acid has been determined based on the method by Barham and Trinder, (1972). Serum creatinine has been determined based on the method by Bartles *et al.,* (1972). Urea was determined as carried out by Fawcett and Scott, (1960).

Statistical Analysis:

Statistical analysis was having out by using SPSS program (V19). Data has been expressed as means ± SEM and the statistical analysis was per formed using one-way analysis of variance followed by Duncan's tests (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Chemical composition of wheat, oat and chia seeds flour:

The macronutrient makeup of the wheat, oat, and chia flour samples was detailed in Table 1's proximate analysis results. According to the data, chia flour had a lower moisture level of 5.90%, whereas wheat flour (72% ext.) and oat flour had the greatest moisture contents, at 11.48 and 10.76%, respectively. These findings concur with Mesias *et al.* (2024) and Mahmoud *et al.* (2023). The highest amount of crude fiber was found in chia flour (25.40%), which was followed by oat flour (12.40%). In contrast, the lowest crude fiber concentration (0.67%) was found in wheat flour (72% ext.) These findings concur with those of Rabail *et al.* (2022) and Biro *et al.* (2020).

Additionally, at 23.40 and 6.86 percent, respectively, chia flour and oat flour had the greatest fat contents. Meanwhile, the lowest fat content, 0.98%, was found in wheat flour (72% ext.). These findings are consistent with those of Mishra and Khasherao (2023) and Abo-Zaid (2023).

The highest ash content was found in oat flour (6.23%), which was followed by chia flour (3.90%). However, the lowest ash concentration (0.56%) was found in wheat flour (72% ext.). These findings concur with those of Mesias *et al.* (2024) and Abo-Zaid (2023).

Conversely, oat flour had the highest protein content, at 15.70%, followed by chia flour at 13.10%. The protein content of wheat flour (72% ext.) was the lowest, at 10.28%. The results are consistent with those of Abo-Zaid (2023) and Grancieri *et al.* (2019).

The maximum amount of accessible carbs was found in wheat flour (72% ext.), which was followed by oat flour (87.51 and 58.81%, respectively). Chia flour, on the other hand, has the fewest carbs (34.20%). These findings concur with those of Mishra and Khasherao (2023) and Biro *et al.* (2020).

Table 1. Chemical composition of wheat, oat and chia seeds flour

	Chemical composition (%)					
	Moisture	**Protein**	**Fiber**	**Fat**	**Ash**	***Available carbohydrates**
Wheat flour	11.48^{a}±0.10	10.28^{b}±0.09	0.67^{ab}±0.02	0.98^{a}±0.014	0.56^{b}±0.020	87.51^{a}±1.75
Oat flour	10.76^{a}±0.11	15.70^{a}±0.08	12.40^{a}±1.56	6.86^{b}±1.41	6.23^{b}±0.024	58.81^{a}±2.05
Chia flour	5.90^{b}±0.09	13.10^{ab}±0.08	25.40^{a}±1.05	23.40^{a}±2.011	3.90^{a}±0.026	34.20^{ab}±1.23

*** Available carbohydrates calculated by deference**

Minerals content of wheat, oat and chia seeds flour:

According to the findings in Table (2), chia flour had a reduced salt concentration (15.60 mg/100 g), while wheat flour (72% ext.) and oat flour had the greatest sodium contents (26.35 and 20.00 mg/100 g, respectively). According to the data, oat flour had the highest potassium and manganese level, measuring 429.00 and 4.92 mg/100 g, respectively. Wheat and chia flour came in second and third, with respective contents of 95.23, 0.78, and 4.70 and 2.71 mg/100 g.

In addition, when compared to wheat and oat flours, chia flour has the highest concentrations of calcium, magnesium, phosphorus, iron, zinc, and copper. It had the following values: 630.00, 335.00, 860.88, 7.69, 4.52, and 0.92 mg/100g, respectively. Oat flour came in second with values of 55.00, 175.00, 523.00, 4.71, 3.96, and 0.64 mg/100g. In contrast, wheat flour has the following mineral contents: 10.75, 23.14, 75.42, 0.67, 0.38, and 0.25 mg/100g.

The calcium, potassium, sodium, magnesium, phosphorous, iron, and zinc contents of chia flour were 631.0, 407.0, 16.0, 335.0, 860.0, 7.7, and 4.6 mg/100g, respectively, according to the results obtained, which agreed with Kulczynski *et al.* (2019). Additionally, oat flour's calcium, potassium, sodium, and iron contents were 8.94, 534.98, 403.13, and 6.01 mg/100g, respectively, according to Suzauddula *et al.* (2021). Furthermore, P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu levels in chia flour were 860, 407, 631, 335, 16.0, 7.7, 2.7, 4.6, and 0.9 mg/100g, according to Mahmoud *et al.* (2023).

Table 2. Minerals content of wheat, oat and chia seeds flour

	Minerals content (mg/100g)								
	Na	**K**	**Ca**	**Mg**	**Mn**	**P**	**Fe**	**Zn**	**Cu**
Wheat flour	26.35^{a}±1.12	95.23^{a}±2.60	10.75^{b}±0.223	23.14^{b}±0.02	0.87^{bc}±0.014	75.42^{b} ±2.60	0.67^{c}±0.011	0.38^{b}±0.020	0.25^{b}±0.014
Oat flour	20.00^{b}±1.15	429.00^{a}±4.53	55.00^{a}±2.64	175.00^{a} ±2.13	4.92^{b} ±0.02	523.00^{ab}±4.44	4.71^{b} ±0.01	3.96^{b}±0.023	0.64^{ab}±0.016
Chia flour	15.60^{b}±0.84	4.70^{ab}±0.023	630.00^{a}±4.45	335.00^{ab}±4.33	2.71^{ab} ±0.03	860.00^{a} ±4.52	7.69^{ab}±0.026	4.52^{a}±0.023	0.92^{ab}±0.021

Total phenolic, total flavonoids and antioxidant activity of oat and chia seeds flour:

Total phenolic, total flavonoids content and antioxidant activity were determined in oat and chia seed flour and the results are listed in Table (3), which show, that chia seed powder is a good source of total phenols, as it recorded 50.88 (mg /g) in comparison to oat flour which recorded 0.78 (mg/g) phenolic, while the oat flour recorded the highest flavonoids values being 127.32 (mg/g) in comparison to chia flour which recorded 0.45 (mg/g).

Table 3. Total phenolic, total flavonoids and antioxidant activity of oat and chia seeds flour

	Total phenolic (mg/g)	**Total flavonoids (mg/g)**	**Antioxidant activity (DPPH) (mg/g)**
Oat flour	0.78^{a}±0.02	127.32^{a}±3.41	39.77^{ab}±1.74
Chia flour	50.88^{a}±2.02	0.45^{b}±0.01	42.10^{a}±1.62

The highest value for antioxidant activity was 42.10 (mg/g) for chia flour and 39.77 (mg/g) for oat flour. These findings align with the findings of Oliveira-Alves *et al.* (2017). The findings indicate that chia seed powder may contain natural antioxidants and bioactive components that can lower the risk of cardiovascular diseases, inhibit the rancidity of unsaturated fatty acids, and increase antioxidant activity because the seed powder contains phenolic compounds (Reyes-Caudillo *et al.*, 2008 and Marineli *et al.*, 2014).

Physical measurements of biscuit:

The findings in Table (4) demonstrate how the physical measurements of biscuits (weight, volume, and specific volume) are affected when wheat flour (72% ext.) is substituted with varying amounts of oat or chia flour. According to the results, the control sample, which was made entirely of wheat flour, weighed 31.40 g and had a volume of 58 cm3, with a specific volume of 1.85 cm3/g. The weight of the made biscuit increased gradually as the amount of substitution increased when 10, 15, and 20% of oat or chia flour was substituted for wheat flour.

Samples of biscuits containing 10, 15, and 20% oat and chia flour weighed 32.18, 32.71, 34.41, and 36.14, 36.39, and 44.06 g, respectively. The increased biscuit fiber content, which is characterized by a better water-holding ability, could be the cause of the weight rise (Chen *et al*., 1988). Additionally, the ability of chia seed flour to retain oil during biscuit baking (Rufeng *et al*. 1995) and the cookies' increased density (Francine *et al*. 2011) could be the cause of the chia biscuits' increased weight

Table 4. Physical measurements of biscuit prepared by substituted of wheat flour with oat and chia flour

Biscuit samples	Substitution levels (%)	Physical properties of biscuit		
		Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
Control sample	zero	31.40a±1.04	58^{a}±1.12	1.85^{a}±0.04
Oat flour	10	32.18^{a}±1.03	58^{a}±1.11	1.80^{a}±0.03
	15	32.71^{ab}±1.03	58^{a}±1.11	1.77^{ab}±0.01
	20	34.41^{b}±1.00	59^{ab}±1.14	1.72^{ab}±0.01
Chia flour	10	36.14^{ab}±0.98	60^{a}±1.16	1.66^{ab}±0.04
	15	36.39^{b}±1.01	65^{ab}±1.01	1.79^{b}±0.02
	20	44.06^{bc}±1.02	65^{ab}±1.00	1.48^{b}±0.00

Conversely, substituting 10, 15, and 20% oat or chia flour for wheat flour resulted in a progressive drop in biscuit volume as the amount of oat or chia flour increased in comparison to the control sample. The samples' volumes were 58, 58, 59, and 60, 65, 65 cm3 for 10, 15, and 20% oat and chia flour, respectively. The decrease in biscuit volume could be brought about by the addition of oat or chia flour diluting the wheat gluten and increasing the fiber content. These outcomes concur with the findings of Divyashree *et al.* (2016).

As intended, the trends of volume and specific volume values were identical. For the aforementioned level of replacement, it was 1.80, 1.77, 1.72, and 1.66, 1.79, 1.48 cm3/g, respectively.

Texture profile analysis (TPA) of prepared biscuit samples

The results of (TPA) of biscuits made with oat or chia seed flour are presented in Table (5). In general, some substitution ratios showed clear differences in the coefficients of hardness (N), adhesion (MJ), cohesiveness, Gumminess (N), and chewiness (MJ). Where the findings showed that there was an increase in each of the following parameters: hardness, Adhesiveness, Cohesiveness, Gumminess and chewiness as a result of an increase in the replacement percentage of oat flour, while a decrease in the same parameter were occurred with an increase in the replacement percentage of chia seeds flour, compared to the control biscuit sample. Where, whether the increase or decrease that occurred in the biscuit samples, it became clear as a result of the percentage of fat, sugar, and the amount of water added, as the biscuit is thin and easy to break and this is result to the high percentage of fat in chia powder, and These results are consistent with those of Jan *et al.* (2022).

Table 5. Texture profile analysis (TPA) of prepared biscuit samples

Biscuit samples	Texture profile parameters					
	Substitution levels (%)	Hardness (N)	Adhesiveness (mj)	Cohesiveness	Gumminess (N)	Chewiness (mj)
Control sample	zero	92.12	0.40	0.72	66.32	309.00
Oat flour	10	65.57	0.40	0.85	55.70	231.70
	15	93.11	0.60	1.64	152.27	513.20
	20	57.98	0.50	0.83	47.94	165.40
Chia flour	10	51.56	0.00	0.77	39.72	75.50
	15	56.46	0.40	0.63	35.61	90.80
	20	45.18	0.80	0.37	16.68	17.00

The evaluation of Sensory of prepared biscuit

To find the ideal level of substitution for creating high-quality products, the sensory qualities of biscuit samples were assessed. While test samples included 10%, 15%, and 20% substitutions of oat or chia flour for wheat flour, control biscuits were made with 100% wheat flour (72% extraction). The organoleptic characteristics of every sample were evaluated by ten panelists with training (Table 6). These findings concur with those of Wallaa *et al*. (2018), who found that biscuits became darker as the amount of oat flour rose. Also, Divyashree *et al*. (2016) mentioned that, biscuits with higher proportion of chia seed flour were significantly darker than control biscuit sample which prepared from 100% wheat flour (72% ext.).

Regarding flavor, there was no discernible change between the control sample and the 10% oat flour substitution level. Additionally, no discernible variations were found between the control sample and the 10% chia flour substitution level. However, there were notable variations between the control sample and the 20% oat flour substitution level. Significant variations were also noted between the control sample and the 15% and 20% chia flour substitution levels.

There were no discernible variations ($p > 0.05$) in texture between the biscuits made with 100% wheat flour as the control and those that had 10% oat or chia flour substituted. However, at higher substitution levels (15 and 20%), significant differences ($p < 0.05$) were noted. These results are consistent with those of Divyashree *et al.* (2016), who found that increasing substitution levels in composite-flour formulations led to an increase in biscuit hardness.

Additionally, the findings of the sensory evaluation showed that there were no statistically significant differences ($p > 0.05$) in the odor characteristics of the biscuits made with 100% wheat flour as the control and those that had 10%, 15%, or 20% oat or chia flour substituted.

Ultimately, the examined biscuit sample's crust appearance demonstrated that there were no appreciable variations between the control sample and the biscuit samples that included oat flour at a level of substitution of 10% to 15%. Additionally, no discernible variations were found between the control sample and the 10% chia flour substitution level. However, there were notable variations between the control sample and the 20% oat flour substitution level. Significant variations were also noted between the control sample and the 15% and 20% chia flour substitution levels. According to El-Zainy *et al*. (2014), adding more oat flour to biscuits enhances their flavor, aroma, and appearance on the outside but detracts from their texture, color, and acceptability.

The obtained results agree with Syed-Ahmed *et al.* (2018), Goswami and Awasthi (2022) & Hassan *et al.* (2023).

Table 6. Sensory evaluation of prepared biscuit samples

Biscuit samples	Sensory evaluation parameters						
	Substitution levels (%)	Color (10)	Taste (15)	Texture (30)	Odor (15)	Crust appearance (30)	Over all acceptability (100)
Control sample	0	9.52^{ab}±1.78	14.43^{a}±2.02	29.29^{a}±3.11	14.71^{a}±2.33	29.57^{a}±3.01	97.52^{a}±4.11
Oat flour	10	9.64^{a}±1.83	14.29^{a}±2.00	28.71^{ab}±2.52	14.14^{a}±2.30	29.14^{a}±2.76	95.92^{a}±4.13
	15	9.46^{ab}±1.89	14.14^{ab}±2.02	28.44^{b}±2.66	13.71^{b}±2.02	28.71^{ab}±2.54	94.46^{ab}±3.95
	20	8.73^{b}±2.01	13.86^{ab}±1.99	28.43^{b}±2.60	13.72^{b}±2.02	28.57^{b}±2.61	93.31^{ab}±3.97
Chia flour	10	9.21^{a}±1.77	14.29^{ab}±2.03	28.86^{a}±2.53	13.86^{a}±2.31	28.71^{a}±2.55	94.93^{a}±4.00
	15	9.26^{ab}±1.71	13.43^{ab}±1.97	28.29^{ab}±2.52	13.57^{ab}±2.52	28.29^{b}±2.36	92.84^{ab}±3.80
	20	8.82^{b}±2.13	13.41^{ab}±1.96	27.86^{b}±3.10	13.71^{b}±2.60	27.71^{b}±2.30	91.51^{b}±4.12

Biological evaluation of the experimental diet

According to the sensory evaluation of different biscuit samples, the selected biscuit, oat flour and chia flour samples were biologically evaluated for the following parameters

Initial body weight, final body weight and body weight gain of different rats groups

Table (7) shows the initial body weight (g), end body weight (g), and body weight gain (g) of rats fed the various biscuit, oat flour, and chia flour sample diets. The rats were normal (control negative) and high-fat diet rats (control positive). According to the data collected, there was no discernible difference in the starting body weight of any of the rat groups. Rats in the various groups gained weight after being fed the hyperlipidemia diet for 10 days, and then the experimental diet of biscuit, oat flour, and chia flour samples for 45 days. However, it was found that the hyperlipidemia group, which was fed the hyperlipidemia diet exclusively during the entire experimental period (control positive), had more significant differences than the group that was fed only the basal diet. These are most likely the result of feeding exclusively a hyperlipidemia diet for the duration of the experiment.

Table 7. Initial body weight, final body weight and body weight gain of different rats groups

Experimental rat groups	Initial body weight (g)	Final body weight (g)	Body weight gain (g)
G1	253.8^{a} ±4.43	318.2^{bc} ±4.79	64.4^{c} ±2.53
G2	242.8^{a} ±3.94	355.8^{a} ±4.23	113.0^{a} ±3.17
G3	253.2^{a} ±4.41	339.6^{b} ±4.62	86.4^{b} ±2.60
G4	248.8^{a} ±3.41	326.4^{b} ±4.14	77.6^{b} ±2.57
G5	258.2^{a} ±4.42	347.0^{a} ±4.60	88.8^{ab} ±2.61
G6	257.6^{a} ±3.53	335.4^{ab} ±3.87	77.8^{ab} ±2.57
G7	265.2^{a} ±4.17	340.2^{b} ±4.71	75.0^{b} ±2.54
G8	262.8^{a} ±4.21	328.0^{ab} ±4.33	65.2^{c} ±2.53
G9	253.8^{a} ±4.43	345.4^{ab} ±4.81	91.6^{b} ±2.66
G10	258.0^{a} ±4.42	343.4^{b} ±4.66	85.4^{bc} ±2.64

G1: Group fed on basic diet (Negative control).
G2: Group fed on high-fat basal diet (Positive control).
G3: Group fed on high-fat basal diet in addition to 10% oat flour.
G4: Group fed on high-fat basal diet in addition to 20% oat flour.
G5: Group fed on high-fat basal diet in addition to 10% chia flour.
G6: Group fed on high-fat basal diet in addition to 20% chia flour.
G7: Group fed on high-fat basal diet in addition to biscuits containing 10% oat flour.
G8: Group fed on high-fat basal diet in addition to biscuits containing 20% oat flour.
G9: Group fed on high-fat basal diet in addition to biscuits containing 10% chia flour.
G10: Group fed on high-fat basal diet in addition to biscuits containing 20% chia flour.

These findings support Choo's (2003) assertion that rats fed a high-fat diet gained more body weight than the control group, which was fed solely a control basil diet. Additionally, George *et al*. (2004) discovered that after consuming a high-fat diet for a prolonged period of time, the number of fat cells in both mice and rats rose. Additionally, the same table showed that biscuits made with 10 and 20% oat or chia flour substituted for some of the wheat flour dramatically decreased final body weight and body weight gain.

The increased amount of dietary fiber in the diet may be the cause of the decrease in body weight gain. These findings concur with those of Zhao *et al*. (1995), who noted that the animal fed h fishier gained less weight each day. Additionally, the barley diet led to a significant reduction in food intake, body weight gain, and food efficiency ratio, according to Kalra and Jood (1998). Simultaneously, Hecker *et al*. (1998) reported that the rats fed a diet of tortillas supplemented with 2% barley soluble β-glucan had lower body weight and feed consumption than the control.

The physiological effects of two concentrated barley β-glucans (6 g β-glucan per day for 6 weeks) on body weight in hypercholesterolemic men and women were also examined by Smith *et al*. (2008). After six weeks, they reported that barley β-glucan reduced body weight in comparison to the control group.

Serum lipid profile of different rats groups

The effects of various experimental diets on the serum lipid profiles (triglycerides, total cholesterol, and HDL-cholesterol) of rats with normal and hyperlipidemia were displayed in Table (8). Based on the data collected, it was found that the first blood serum triglyceride level was, on average, 87.0 to 96.0 mg/dl. Regarding the blood triglyceride levels of each group at the conclusion of the experiment, it was found that the hyperlipidemia group, which was fed only a high-fat diet for the duration of the experiment, had higher blood triglyceride levels (90.0 mg/dl) than the control group, which was fed only a basal diet (85.0 mg/dl). However, when compared to the hyperlipidemia group, the groups who had the biscuit sample made by partially substituting 10 and 20% oat or chia flour for wheat flour had considerably lower blood triglyceride levels.

These groups' lower blood triglyceride levels might be because the oat and chia flour samples had higher quantities of dietary fiber and β-glucan. Regarding the total cholesterol and HDL-cholesterol data shown in the same table, it was possible to see that the starting values for both had average levels of 142.0–155.0 and 44.0–52.0 mg/dl blood serum, respectively. However, after feeding the experimental groups the experimental diet, the control positive group G2, which was fed only a high-fat diet for the duration of the experiment, had a higher blood total cholesterol level (156.0 mg/dl) than the control group G1, which was fed only the basal diet (151.0 mg/dl). The blood HDL-cholesterol level of the control positive group G2, which was fed just a high-fat diet for the duration of the experiment, was 44.0 mg/dl, lower than that of the control group fed only a basal diet (G1), which had a level of 52.0 mg/dl.

Mott *et al*. (1992) found that a high-cholesterol diet raised the cholesterol content of normal adult baboon bile by 15% compared to baboons fed a very low-cholesterol diet. These results are consistent with their findings. Furthermore, Ahmed (2009) discovered that rats fed a diet high in fat and cholesterol had a highly significant increase ($p<0.01$) in all lipid parameters, including total lipids, triglycerides, total cholesterol, and LDL cholesterol. When compared to the normal group, HDL cholesterol also showed a highly significant decrease ($p<0.01$). At the conclusion of the trial, it was shown that the groups that consumed a hyperlipidemia diet of biscuit samples made by partially substituting 10 and 20% oat or chia flour for wheat flour had considerably lower blood total cholesterol levels than the hyperlipidemia group. the drop in these groups' blood levels of total cholesterol. However, throughout the entire trial, HDL cholesterol rose in comparison to the control positive group G2, which was only fed a hyperlipidemia diet. The higher dietary fiber and β-glucan content of the oat and chia flour samples may be the cause of these groups' lower blood total cholesterol levels. Regarding the dietary fiber impact, a number of theories have been put out to explain how soluble dietary fibers lower cholesterol levels. According to Mälkki (2001), soluble dietary fibers hinder the small intestine from reabsorbing bile acids, which increases the amount of cholesterol used for bile acid synthesis and increases bile acid losses in the feces.

At the same time, the liver's ability to synthesize cholesterol is reduced. This is partially because of decreased insulin secretion, which activates hydroxymethyl-glutaryl-Co A reductase (HMG Co A reductase), a crucial enzyme in the synthesis of cholesterol, and partially because of the liver's changed bile acid profile, particularly the comparatively elevated level of deoxycholic acid, which prevents the synthesis of cholesterol. Furthermore, according to Mehta (2005), soluble fiber reduces serum cholesterol by binding with and increasing the excretion of bile acids. This causes the liver to convert LDL cholesterol into bile acids, which reduces the amount of cholesterol that can be absorbed in the intestines and eliminates it from the blood.

Regarding the impact of β-glucan, Shimizu *et al*. (2008) and Smith *et al*. (2008) reported that in hypercholesterolemic Japanese men, consuming 7.0 g of β-glucan daily for 12 weeks resulted in a significant decrease in serum total cholesterol, low-density lipoprotein cholesterol, and the cholesterol/HDL ratio. Additionally, total and soluble β-glucan seemed to be good indicators of the reduction of cholesterol in rats' liver and serum (Keenan *et al*., 2007). Lipids may be less absorbed or reabsorbed as a result of the viscous nature of soluble β-glucan.

Additionally, when compared to the control, the chia diet significantly increased the concentration of HDL cholesterol, significantly decreased total cholesterol, and significantly reduced serum triglycerides (Ayerza and Coates, 2011). Both whole and crushed chia seeds improved the rats' lipid profiles after 30 days of consumption (Ayerza and Coates 2007).

Nevertheless, according to Oliva *et al*. (2013), rats given chia seeds for three weeks had TG levels that were noticeably lower than those of the control groups. Alamri (2019) discovered that chia seeds, both black and white, reduced triglycerides and total cholesterol in diabetic rat treatment groups as compared to control groups. Additionally, the mean total cholesterol levels for the diabetic and normal control groups were 256 and 105 mg/dl, respectively, according to Khafagy and Hendawy (2022).

Table 8. Serum lipid profile of different rats groups

Experimental rat groups	Serum lipid profile					
	Triglycerides (mg/dl)		Total cholesterol (mg/dl)		HDL- cholesterol (mg/dl)	
	Initial period	Final period	Initial period	Final period	Initial period	Final period
G1	$96^{ab}\pm2.35$	$85^{a}\pm2.27$	$155^{b}\pm2.51$	$151^{ab}\pm2.51$	$47^{a}\pm3.46$	$52^{a}\pm3.17$
G2	$94^{a}\pm2.33$	$90^{a}\pm2.27$	$148^{a}\pm4.91$	$156^{a}\pm4.36$	$52^{a}\pm3.17$	$46^{a}\pm3.36$
G3	$94^{a}\pm2.23$	$77^{a}\pm2.26$	$153^{a}\pm4.33$	$142^{a}\pm4.33$	$44^{a}\pm3.36$	$48^{a}\pm3.17$
G4	$93^{b}\pm2.11$	$77^{ab}\pm2.32$	$147^{a}\pm4.91$	$136^{a}\pm2.55$	$44^{a}\pm3.17$	$49^{a}\pm3.17$
G5	$94^{b}\pm2.21$	$72^{ab}\pm2.35$	$150^{b}\pm5.20$	$133^{ab}\pm4.90$	$51^{a}\pm3.16$	$51^{a}\pm3.43$
G6	$92^{b}\pm2.33$	$74^{ab}\pm2.33$	$148^{b}\pm4.63$	$137^{ab}\pm4.33$	$45^{a}\pm3.23$	$48^{a}\pm3.23$
G7	$88^{b}\pm2.31$	$77^{b}\pm2.34$	$142^{b}\pm2.51$	$133^{b}\pm4.91$	$45^{a}\pm3.17$	$50^{a}\pm3.17$
G8	$87^{ab}\pm2.34$	$82^{b}\pm2.26$	$144^{ab}\pm5.21$	$135^{ab}\pm2.51$	$47^{ab}\pm3.18$	$52^{a}\pm3.36$
G9	$94^{b}\pm2.34$	$83^{b}\pm2.28$	$145^{b}\pm2.51$	$139^{ab}\pm4.36$	$45^{ab}\pm3.15$	$49^{a}\pm3.48$
G10	$93^{ab}\pm2.33$	$79^{b}\pm2.33$	$154^{b}\pm4.90$	$130^{ab}\pm2.50$	$45^{ab}\pm3.15$	$50^{a}\pm3.17$

Liver functional profile of different rats groups

The results of liver functions (ALT and AST) in serum are presented in Table (9).

The data showed that ALT and AST activities were significantly stimulated in G2 (hyperlipidemia group) relative to G1 (normal control).

However, all treated groups had improved ALT and AST activities relative to G2 (hyperlipidemia group) but these activities were still higher than that of normal control.

The data in the same Table (9) revealed that serum alkaline phosphatase (ALP) was increased significantly in G2 (hyperlipidemia group) compared to G1 (normal control). While, the treatment groups (G3-G10) which fed on biscuits prepared with partially replacement with oat and chia seeds flours significantly inhibited ALP activity to normal levels, respectively.

According to Mohd Ali *et al*. (2012), Sargi *et al*. (2013), and Valdivia-López and Tecante (2015) reported that when feeding chia seeds has been associated with improvements in lipid profiles and liver function. This is because chia seeds contain a lot of ω-3 fatty acids. da Silva Marineli *et al*. (2014) and Da Silva *et al*. (2016) shown that by lowering the levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST), chia seeds can effectively lower indicators of liver injury.

According to Khafagy and Hendawy (2022), the mean AST values for diabetes and normal control groups were 162 and 128 (U/L), respectively. Rats fed a basal diet containing chia seeds (5%) were 111 (U/L) as compared to a control group of diabetes individuals. It was noticeable that the mean ALT values for the diabetes control group were 128 and 38 (U/L), respectively, when higher than those for the normal control group.

Table 9. Liver functional profile of different rats groups

Experimental rat groups	Liver functional profile			
	AST		ALT	
	Initial period	Final period	Initial period	Final period
G1	25ᵃ±2.60	22ᵃ±1.43	26ᵇ±2.54	27ᵃᵇ±2.55
G2	24ᵃᵇ±2.31	24ᵃ±2.30	32ᵃ±2.51	26ᵃ±2.60
G3	20ᵃᵇ±1.46	26ᵃᵇ±1.50	31ᵃ±2.51	27ᵃ±2.61
G4	25ᵃᵇ±1.43	17ᵃᵇ±2.01	35ᵃᵇ±2.61	32ᵃ±2.02
G5	26ᵃᵇ±1.51	13ᵇ±2.34	37ᵃᵇ±2.66	30ᵃ±2.51
G6	24ᵃᵇ±1.4	23ᵃᵇ±1.41	36ᵃᵇ±2.65	29ᵃᵇ±2.51
G7	19ᵇ±1.43	30ᵃᵇ±2.51	31ᵃᵇ±2.02	21ᵃᵇ±1.44
G8	17ᵇ±2.02	25ᵇ±1.43	26ᵃᵇ±1.44	17ᵃᵇ±1.46
G9	20ᵇᶜ±1.43	23ᵇ±2.33	30ᵇ±1.46	20ᵃᵇ±1.40
G10	23ᵇᶜ±2.60	25ᵇ±2.02	27ᵃᵇ±1.43	21ᵃᵇ±2.02

Kidney functional profile of different rats groups

The kidney functions such as urea and creatin values are presented in Table (10). The data showed that urea was significantly increased in G2 (hyperlipidemia group) compared with G1 (normal control). However, treatments of (G3-G10) which fed on biscuits prepared with partially replacement with oat and chia seeds flours significantly decreased serum urea of hyperlipidemia rats to the normal levels. Also, the results in the same Table (10) revealed that creatin content was significantly increased in G2 (hyperlipidemia group) compared to normal control but all hyperlipidemia rats had low creatin content with significant differences between them.

According to Khafagy and Hendawy (2022) Found that, the mean values of creatinine in the diabetes control group and the normal control group, respectively were 1.54 and 0.70 mg/dl. When comparing to a diabetic control group, treated rats fed a basal diet containing chia seeds (5%) had creatinine levels that were 0.56 mg/dl lower. It was clear that the mean urea values for the diabetic and normal control groups, 82 and 17 mg/dl, respectively, were higher. Compared to a diabetic control group, rats fed a basal diet containing chia seeds (5%) had 36 mg/dl when comparing to a diabetic control group.

Table 10. Kidney functional profile of different rat's groups

Experimental rat groups	Kidney functional profile			
	Urea		Creatin	
	Initial period	Final period	Initial period	Final period
G1	25ᵇ±1.43	25ᵃ±1.43	0.95ᵃᵇ±0.03	0.88ᵃᵇ±0.02
G2	31ᵃᵇ±2.33	22ᵃ±1.43	0.90ᵃᵇ±0.03	0.88ᵃᵇ±0.03
G3	25ᵃ±2.02	28ᵃ±1.43	0.94ᵇ±0.02	0.85ᵃᵇ±0.03
G4	22ᵃᵇ±2.60	35ᵃ±1.43	0.93ᵇ±0.04	0.91ᵃᵇ±0.04
G5	16ᵇ±2.02	29ᵃᵇ±1.43	0.91ᵇ±0.02	0.87ᵇ±0.03
G6	14ᵃᵇᶜ±2.00	26ᵃᵇ±1.43	0.90ᵃᵇ±0.02	0.88ᵃᵇ±0.02
G7	20ᵇᶜ±2.33	27ᵇ±1.43	0.93ᵇᶜ±0.03	0.87ᵇ±0.03
G8	23ᵇ±1.45	26ᵃᵇ±1.43	0.93ᵃᵇᶜ±0.03	0.90ᵃᵇ±0.03
G9	22ᵇᶜ±1.47	26ᵇ±1.43	0.91ᵇᶜ±0.02	0.87ᵇ±0.03
G10	26ᶜ±2.31	22ᵇᶜ±1.43	0.94ᶜ±0.04	0.94ᵇᶜ±0.02

According to the study, up to 20% of oat and chia seeds should be used while making nutritious meals, which will raise the amount of protein and fiber. The findings show that consuming meals including oat and chia seeds decreased TG, TC, LDL-C, and VLDL-C. Additionally, combining oat and chia seed flour with wheat flour resulted in diets that improved health and reduced body weight.

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تأثير البسكويت المصنع من دقيق الشوفان وبذور الشيا علي الفئران التي تتغذي علي وجبات عالية الدهون

مسعد عبد العزيز أبو ريه[١]، جيهان علي عوض غنيم[١]، أكرم محمد محمد العناني[٢] والحايطي محمد عوض[١]

[١]اقسم الصناعات الغذائية، كلية الزراعة، جامعة المنصورة

[٢]قسم الصناعات الغذائية ، معهد بحوث تكنولوجيا الأغذية، مركز البحوث الزراعية، الجيزة، مصر

الملخص

تم اجراء البحث لدراسة تأثير استبدال دقيق القمح (٧٢٪) المستخدم في تصنيع البسكويت بدقيق كلا من الشوفان وبذورالشيا بنسب مختلفة ١٠، ٢٠،١٥٪ على التركيب الكيميائي للبسكويت المصنع مقارنة بالعينة الكنترول . أظهرت النتائج حدوث زيادة في محتوى البروتين والألياف مع زيادة نسبة اضافة دقيق الشوفان وبذور الشيا في البسكويت.كما اظهرت نتائج الاختبارات الحسية والفيزيائية ان العينة الكنترول (١٠٠ % دقيق قمح) سجلت اعلي قيم في صفات الحجم مقارنة بمثيلتها المصنعة باضافة دقيق الشوفان والشيا حيث وصلت نسبة الاستبدال الي ١٥٪ . سجلت عينة البسكويت الكنترول المصنعة من (١٠٠٪ دقيق قمح)أعلى قيمة حجمية عند مقارنته ببسكويت دقيق الشوفان والشيا. يمكن تحضير بسكويت مغذي بخلال استبدال دقيق القمح بنسبة تصل إلى ١٥٪ بدقيق الشوفان أو بذور الشيا دون آثارسلبية على قبول البسكويت المحضرة، تم تأثير استخدام بسكويت كلا من دقيق الشوفان وبذور الشيا بنسب مختلفة كبديل لدقيق القمح على الفئران التي تتغذى على وجبات عالية الدهون لمدة ٨ أسابيع،واوضحت النتائج البيولوجية إلى أن التغذية على الوجبات التي تحتوي على دقيق الشوفان والشيا بمستويات أعلى أدت إلى انخفاض وزن جسم الفئران مقارنة بالمجموعة الكنترول ،كما لوحظ انخفاض في مستوي الدهون الثلاثية،الكوليسترول الكلي،الكوليسترول الضار،الكوليسترول منخفض الكثافة في مجموعات الفئران التي تغذت على البسكويت عالي الدهون،الذي استبدل بدقيق الشوفان وبذور الشيا مقارنة بالفئران التي تغذت على مجموعة النظام الغذائي الأساسي عالي الدهون. وظائف الكبد والكلى للفئران التي تغذت على البسكويت عالي الدهون المحتوي على دقيق الشوفان أو دقيق بذور الشيا أقل من تلك التي تغذت على مجموعة النظام الغذائي الأساسي عالي الدهون،تظهر النتائج أن الفئران التي تغذت على نظام غذائي أساسي عالي الدهون لديها أعلى وزن للكبد والكلى والقلب، الفئران التي تغذت على البسكويت عالي الدهون المستبدل بمستوى أعلى من دقيق الشوفان والشيا لديها أقل وزن للأعضاء،توصي الدراسة باضافة دقيق الشوفان وبذور الشيا مع دقيق القمح في اعداد الوجبات الغذائية لتقليل وزن الجسم وتحسين الحالة الصحية

الكلمات الدالة:دقيق الشوفان-دقيق بذور الشيا -البسكويت-الخصائص الكيميائية والفيزيائية- الخصائص الحسية-التقييم البيولوجي.