BIO Web of Conferences **178**, 02001 (2025) https://doi.org/10.1051/bioconf/202517802001
8th AMIFOST 2025

The Formulation of Nutritious Vegan Burger Patty Incorporating Millet: a better Plant-Based Substitute

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Abstract. The purpose of this research is to formulate a healthy vegan burger patty from foxtail millet, proso millet, and sweet potato. Four formulations (S1–S4) were made with different ratios and compared with a conventional potato control. Sensory analysis on a 9-point hedonic scale revealed that the highest acceptability (7.85 ± 0.25) was exhibited by sample S3 (15% foxtail millet, 15% proso millet, 70% sweet potato), which closely resembled the control. The nutritional evaluation indicated S3 had a much higher content of protein (13.40 ± 0.20 g), fiber (10.70 ± 0.20 g), and mineral composition—iron (2.50 ± 0.05 mg), calcium (74.50 ± 1.25 mg), zinc (9.16 ± 0.15 mg), and potassium (70.90 ± 0.75 mg)—with $p < 0.001$. Vitamin A was much higher (43.00 ± 1.00 IU) than the control value (12.00 ± 1.00 IU). The findings emphasize the ability of millet and sweet potato to enhance the sensory and nutritional attributes of plant-derived vegan patties.

KEYWORDS: Burger-patty, Foxtail millet, Proso millet, sweet potato, Vegan.

1. INTRODUCTION

The global vegan food market has been through meaningful growth in recent years, driven by rising health consciousness, ecological concerns, and ethical considerations. Studies indicate that by 2025, it is estimated that the market demand for plant-based goods will be about 27.5 billion USD, with younger generations, particularly Gen Z, playing an important role in this trend [1, 2]. It is expected to grow quite steadily, with the increasing innovation in plant-based and clean meat technologies. Many companies are emphasizing further improving the sensory attributes of vegan products so they can be more appealing to a broader consumer base [2, 3]. Indian consumers are noticeably drawn more to plant-based diets because of perceived health benefits, such as greatly improved digestion and substantially reduced hormonal imbalances [4, 5]. India's overall cultural and religious landscape, which often promotes vegetarianism, has created a fertile ground for the further growth of the vegan market. However, incorporating dairy products within customary diets poses a challenge to complete vegan adoption [6, 7]. The Indian vegan market is self-assured of significant growth, particularly in tier 2 and 3 cities; in those locations, there is a growing interest in health and sustainability. However, dealing with price sensitivity as well as increasing awareness will be critical for common adoption [1]. Millets, a nutritious grain, have a high amount of protein, dietary fiber, vitamins, and minerals, so they are helpful for vegetarian diets. They are predominantly cultivated in arid and semi-arid regions, particularly in Asia and Africa, in which they are truly a staple food source. They contain many phenolic acids and several antioxidants, which can help lower the chance of chronic diseases such as diabetes and cardiovascular issues. Proso millet (*Panicum miliaceum*) and foxtail millet *(Setaria italica*) are several small-grained bowls of cereals known for their high nutritional value, including protein, dietary fibre, and minerals. These millets are gluten-free; therefore, they are good for gluten-intolerant consumers. Their minute grain size, in conjunction with high starch content, makes them ideal for texturization and also for binding in plant-based patties [8]. Foxtail millet usually contains approximately 60-65 g of carbohydrates and 12.3 g of protein, along with 6 g of dietary fiber for each 100 g. It is also a good source, particularly of necessary minerals, including phosphorus, calcium, iron, zinc, magnesium, and sodium [9]. Proso millet contains approximately 12.10% protein as well as 5.55% crude fiber, making it a nutritious gluten-free option. Sweet potatoes are indeed rich in bioactive compounds such as carotenoids, flavonoids, and anthocyanins, along with phenolic acids, which contribute to their health benefits. Sweet potatoes exhibit powerful antioxidant properties, which help combat oxidative stress as well as decrease chronic disease risk. They have been shown to improve glucose regulation as well as insulin sensitivity. Sweet potato starch is used in diverse food products on account of its special physicochemical properties, such as gelation and digestibility. Dietary fiber coming from sweet potatoes improves gut health in addition to regulating fat and glucose levels, making it suitable for functional food applications [10]. The research targeted evaluating the optimal influence of sweet potato-millet flour blends on some sensory quality attributes (colour, texture, and sensory) of the vegan burger patty.

2.MATERIALS AND METHODS

2.1 Materials

2.1.1 Procurement of Raw Material:

Raw ingredients such as foxtail millet, proso millet, sweet potato, spices, and oil were procured from the local market at Mohali, Punjab.

2.2 Methodology

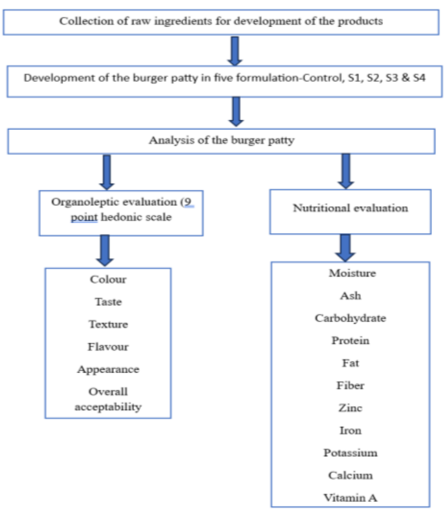


Figure 1: Methodology of the study.

2.2.1 Formulation of Burger Patty:

The foxtail millet and proso millet were ground into fine powder & roasted in a pan separately. The binding ingredient for the formulation of the burger patty was sweet potato, which was semi-boiled for 10-12 minutes in a pressure cooker at high temperatures. After peeling the sweet potato, it was grated with the grater. Millet flour was added with sweet potato in different proportions to prepare different formulations. 50% millet flour (25% foxtail & 25% proso) was added with 50% sweet potato to prepare sample S1. 50% millet flour (25% foxtail & 25% proso) was added with 50% sweet potato to prepare sample S1. 40% millet flour (20% foxtail & 20% proso) was added with 60% sweet potato to prepare sample S2. 30% millet flour (15% foxtail & 15% proso) was added with 70% sweet potato to prepare sample S3. 20% millet flour (10% foxtail & 10% proso) was added with 80% sweet potato to prepare sample S4. For the control sample, a Potato burger patty is used that contains 70% boiled white potato & 30% soaked rice flakes. Different formulations for sensory attribution of millet-based burger patty are shown below in Table 1. After preparing the formulation, the samples were shaped uniformly using a mold, covered with cling paper & kept in the refrigerator for 15-20 minutes to set at 7°c. After that, burger patties were coated with breadcrumbs after dipping into corn flour slurry & shallow fried with 5gm oil for each patty for 10-15 minutes at low to medium temperature.

Table 1: Different Ratios of Formulation of Vegan Burger Patty

Sample	White potato	Rice Flaks	Foxtail millet	Proso Millet	Sweet potato
Control *	70%	30%	-	-	-
S1*	-	-	25%	25%	50%
S2*	-	-	20%	20%	60%
S3*	-	-	15%	15%	70%
S4*	-		10%	10%	80%

*In each sample, 5 grams of oil, 5 grams of onion & 5 grams of garlic, and ½ teaspoon salt are added to enhance the taste of a burger patty per 100.

2.2.3 Organoleptic Analysis:

Sensory evaluation was performed on four burger patty types and a control. A 9-point hedonic scale was employed for rating overall preference due to taste, aroma, texture, and appearance. Twelve panellists were involved in the evaluation to judge the acceptability of each type.

2.2.4 Nutritional Evaluation of Developed Vegan Burger Patty:

The analysis of Proximate composition—moisture, ash, carbohydrate, protein, crude fiber, and fat content—along with minerals (calcium, iron, zinc, and potassium) and vitamin A was determined for the vegan burger samples. These were analyzed in the patties made from foxtail millet and sweet potato and compared with those that were formulated from conventional potato-based ingredients.

2.2.4.1 Proximate Analysis

Standard analytical procedures were employed to analyse the proximate constituents, i.e., moisture, ash, crude protein, crude fat & crude fiber. The moisture content was determined by weighing 5 grams of the sample and drying it in a hot air oven at 105°C until constant weight. Nitrogen content was estimated by the macro-Kjeldahl method and converted to protein by using a factor of 6.25. The Soxhlet apparatus was utilized to measure fat content. A sample that was free from moisture was introduced into the assembly, and petroleum ether was utilized as the solvent. The fat was weighed after the extraction when the solvent evaporated. To determine fiber content, a dried sample of 5g was boiled using 200 ml of 1.25% H_2SO_4 for 30 minutes. The solution was filtered and washed using hot water. It was again boiled with 200 ml of 1.25% NaOH, filtered through Whatman filter paper, and washed using hot water until it was free of NaOH. By placing the sample into a previously dried crucible and heating it for two hours at 130°C in a hot air oven, the quantity of ash was determined. Then the crucible was left in the muffle furnace for four hours at 550°C. After cooling down, the residue was weighed to determine ash content. Carbohydrate content was estimated by subtracting the total of moisture, protein, fat, fiber, and ash from 100 [11].

2.2.4.2 Mineral Analysis

To quantify the mineral content, samples were digested with a combination of three acids: nitric acid (HNO_3), sulfuric acid (H_2SO_4), and perchloric acid ($HClO_4$) in a ratio of 10:4:1. This helped decompose the sample matrix to liberate minerals for analysis. After digestion, the blend was diluted and filtered to achieve a final volume of 100 ml. The filtered solutions were then examined for mineral content, such as iron, zinc, potassium, and calcium. These minerals were measured by atomic absorption spectrophotometry by comparing them against standard solutions of the respective minerals [12]

2.2.4.3 Vitamin Analysis

The estimates of vitamin A were carried out by HPLC under AOAC Official Method 2001 13 on the basis that the extraction is efficiently carried out by saponification and the separation can be done through reverse phase chromatography. About 5 g of homogenized sample was processed by saponification of ethanolic potassium hydroxide in the presence of butylated hydroxytoluene (BHT) as an antioxidant to release retinol from the esterified form. Removed unsaponifiable matter was extracted by hexane in a mixture of deionized water until neutral pH was reached, and then evaporated under low pressure, reconstituted in methanol and filtered before being injected into the HPLC system. The separation method was carried out on a C18 reversed-phase column with methanol as the mobile phase. Detection was done at 325 nm using a UV detector. Quantification was done by comparing peak areas from the samples to standard vitamin A solutions.

2.2.4.4 Statistical Analysis:

Excel was employed to compare all of the data in a single way using the mean and standard deviation. Statistical analysis was done with SPSS (version 26). The sensory and nutritional parameters were analyzed for comparison between value-added products produced from foxtail, proso millet, and sweet potatoes using one-way ANOVA and the t-test.

3. RESULT AND DISSCUSION

3.1 Organoleptic Evaluation of Burger Patty:

The organoleptic characteristics, including colour, appearance, flavour, taste, texture and overall acceptability, were evaluated for the burger patty. The scores received for the Control Sample & testing samples S1, S2, S3 and S4 are given below in Table 2. The analysis indicates that sample S3 exhibited the highest overall acceptance among the four testing samples, suggesting that it was preferred by the evaluators in terms of sensory attributes. The sensory analysis of the control and processed samples (S1–S4) showed significant variations ($p < 0.05$) in all the parameters measured, namely colour, appearance, taste, flavour, texture, and overall acceptability (Table 2). The control sample gave the highest mean scores in every sensory attribute at 8.30 ± 0.20 for colour, 8.15 ± 0.18 for appearance, 8.23 ± 0.21 for taste, 8.38 ± 0.19 for flavour, 8.15 ± 0.22 for texture, and 8.30 ± 0.17 for acceptability. From the samples formulated, S3 gave consistently higher sensory performance, whose values closely compared to those of the control. Interestingly, S3 had 7.92 ± 0.23 for color, 7.76 ± 0.19 for appearance, 7.92 ± 0.24 for taste, 7.92 ± 0.22 for flavor, 7.76 ± 0.22 for texture, and 7.85 ± 0.25 for overall acceptability. No significant differences ($p > 0.05$) were found between S3 and the control for colour, taste, and overall acceptability, which showed that S3 was highly accepted by the sensory panel. Conversely, sample S4 was rated lowest for sensory qualities in most attributes, specifically appearance (7.10 ± 0.23), taste (7.05 ± 0.31), flavour (7.00 ± 0.14), texture (6.95 ± 0.33), and overall acceptability (7.10 ± 0.28), implying lower consumer preference. S1 and S2 had intermediate ratings, with S2 being slightly superior to S1 for taste, flavour, and overall acceptability. Analysis of variance (ANOVA) proved highly significant differences among samples for all sensory properties: color ($F = 4.7$, $p < 0.001$), appearance ($F = 6.1$, $p < 0.001$), taste ($F = 9.2$, $p < 0.001$), flavor ($F = 8.1$, $p < 0.001$), texture ($F = 7.0$, $p < 0.001$), and general acceptability ($F = 10.2$, $p < 0.001$). These findings suggest that the formulation significantly influenced sensory attributes, and S3 was found to be the best among the variants developed.

Table 2: Statistical Analysis of Sensory Attribution of Vegan Burger Patty

Sample	Color	Appearance	Taste	Flavor	Texture	Overall Acceptability
Control	**8.30 ± 0.20^a**	**8.15 ± 0.18^a**	**8.23 ± 0.21^a**	**8.38 ± 0.19^a**	**8.15 ± 0.22^a**	**8.30 ± 0.17^a**
S1	7.41 ± 0.25^b	7.20 ± 0.24^b	7.10 ± 0.27^c	6.90 ± 0.30^d	7.00 ± 0.28^c	7.15 ± 0.26^c
S2	7.50 ± 0.22^b	7.35 ± 0.21^b	7.25 ± 0.26^b	7.20 ± 0.25^c	7.10 ± 0.20^c	7.30 ± 0.23^b
S3	**7.92 ± 0.23^a**	**7.76 ± 0.19^a**	**7.92 ± 0.24^a**	**7.92 ± 0.22^b**	**7.76 ± 0.22^b**	**7.85 ± 0.25^a**
S4	7.30 ± 0.26^b	7.10 ± 0.23^b	7.05 ± 0.29^c	7.00 ± 0.31^d	6.95 ± 0.33^d	7.10 ± 0.28^c
F-value	**4.7*** **	**6.1*** **	**9.2*** **	**8.1*** **	**7.0*** **	**10.2*** **

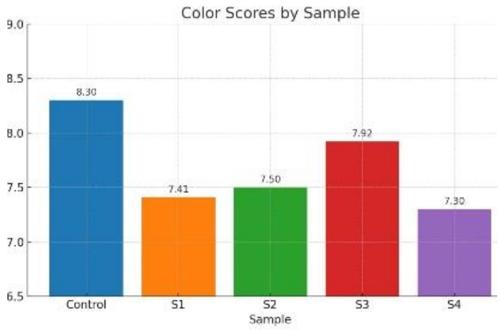
Mean ± Standard Error is utilized, n = 3 replicates × 10 panellists.

• There are significant differences among means, and these are marked with superscript letters (a, b, c, and d) (Tukey's HSD test, $p < 0.05$).

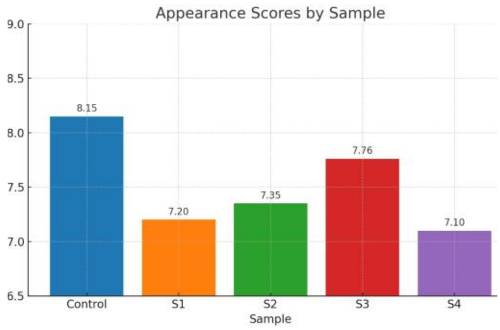
• Levels of significance:

- * p < 0.05
- ** p < 0.01
- *** p < 0.001

https://doi.org/10.1051/bioconf/202517802001



(a)



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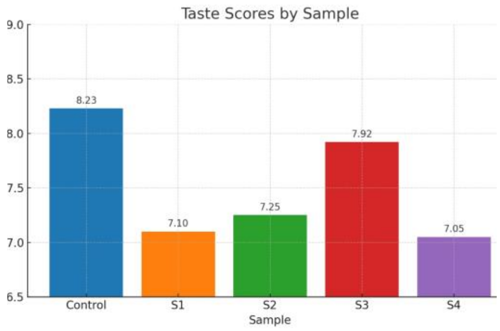

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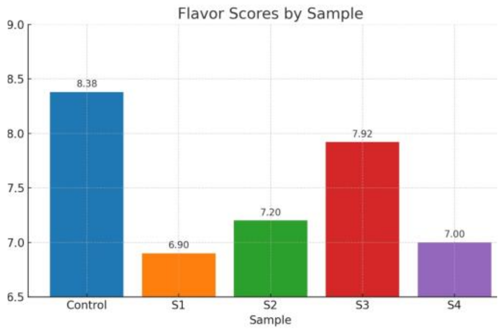

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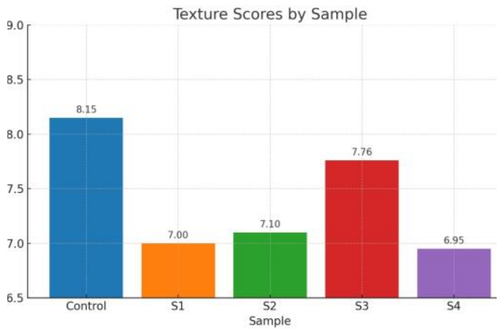

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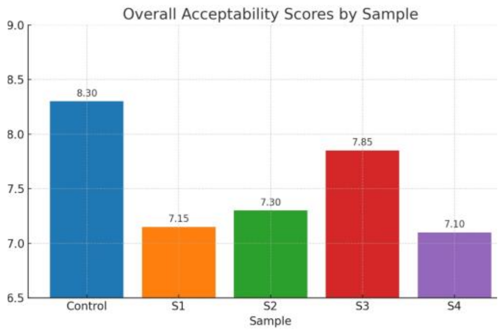

(f)

Figure 2: Graphical presentation of sensory attribution in 9 (Nine) point hedonic scale based on (a) colour, (b) appearance, (c) taste, (d) flavour, (e) texture, (f) overall acceptability

3.2 Nutritional Composition of Value-Added Burger Patty:

Table 3 shows the nutritional content (per 100 g) of the control and the accepted sample. There were significant differences ($p < 0.05$) in all analyzed nutrients, which meant that formulation played a very influential role in the nutritional content. The accepted sample had a considerably lower moisture content (51.10 ± 0.65%) than the control (54.70 ± 0.60%), with a p-value of 0.026. Conversely, the ash content rose significantly in the accepted sample (2.79 ± 0.08%) compared to the control (0.97 ± 0.04%), and it was highly significant ($p < 0.001$). The carbohydrate content in the accepted sample (28.41 ± 0.45 g) was much lower compared to the control (34.51 ± 0.60 g, $p = 0.006$), whereas the protein content was found to be higher than three times (13.40 ± 0.20 g vs. 4.30 ± 0.21 g, $p < 0.001$). Likewise, fiber content was markedly higher in the accepted sample (10.70 ± 0.20 g) than that of the control (4.21 ± 0.15 g, $p < 0.001$). The overall fat content also went down drastically (4.30 ± 0.15 g vs. 5.52 ± 0.20 g, $p = 0.023$). A significant improvement was noted in mineral content, such as iron (2.50 ± 0.05 mg vs. 0.10 ± 0.01 mg), calcium (74.50 ± 1.25 mg vs. 19.00 ± 0.40 mg), zinc (9.16 ± 0.35 mg vs. 1.60 ± 0.04 mg), and potassium (70.90 ± 0.75 mg vs. 20.00 ± 0.40 mg), all with very significant differences ($p < 0.001$). In addition, Vitamin A was significantly greater in the accepted sample (43.00 ± 1.00 IU) than in the control (12.00 ± 1.00 IU), with statistical significance at $p < 0.001$. These results indicate the nutritional improvement attained in the accepted sample, especially in protein, fiber, minerals, and vitamin content, with lower levels of fat and carbohydrates.

Table 3: Statistical analysis of nutritional Composition of control & value-added patty:

Nutrition Composition (per 100g)	**Control Sample (Mean ± SD)**	**Accepted Sample (Mean ± SD)**	**T-statistic**	**P-value**	**Significance**
Moisture (%)	54.70 ± 0.60	51.10 ± 0.65	4.12	0.026	*
Ash (%)	0.97 ± 0.04	2.79 ± 0.08	-18.95	<0.001	***
Carbohydrate (g)	34.51 ± 0.60	28.41 ± 0.45	5.41	0.006	**
Protein (g)	4.30 ± 0.21	13.40 ± 0.20	-14.72	<0.001	***
Total Fat (g)	5.52 ± 0.20	4.30 ± 0.15	4.25	0.023	*
Fiber (g)	4.21 ± 0.15	10.70 ± 0.20	-19.63	<0.001	***
Iron (mg)	0.10 ± 0.01	2.50 ± 0.05	-24.91	<0.001	***
Calcium (mg)	19.00 ± 0.40	74.50 ± 1.25	-19.35	<0.001	***
Zinc (mg)	1.60 ± 0.04	9.16 ± 0.15	-20.17	<0.001	***
Potassium (mg)	20.00 ± 0.40	70.90 ± 0.75	-20.52	<0.001	***
Vitamin A (IU)	12.00 ± 1.00	43.00 ± 1.00	-10.39	<0.001	***

4. CONCLUSION

The present investigation successfully showed how proso millet, foxtail millet, and sweet potato could be functional ingredients when developing a vegan burger patty rich in nutrients. Among all of the various formulations tested, sample S3—comprising 15% proso millet, 15% foxtail millet, and 70% sweet potato—emerged as the most sensorially acceptable, reflecting an overall balanced integration of taste, texture, and nutritional value. The findings do reinforce the viability of incorporating underutilized grains such as millet into mainstream plant-based food products, in offering a healthier, gluten-free alternative to more conventional patties. This formulation aligns not only with consumer demand growing for sustainable, clean-label, and plant-based diets, but it also contributes to consumption promotion of millet consumption, particularly in regions where these crops are already cultivated. Additional future research may explore the shelf life and commercial scalability. Future research may additionally explore the nutritional profiling of such patties to further advance their application in the food industry.

REFERENCE

I. Rybicka, K. Bohdan, P. Kowalczewski. Meat alternatives – market and consumption. 10.18559/978-83-8211-209-2/8 (2024).

2. N. Dhawan, K.Y. Choo. New Meat on the Block: Factors Influencing India's Gen Z's Decision to Purchase Plant-based Meat. J. Student Res. **10(2)** (2021).

3. B. Safdar, H. Zhou, H. Li, J. Cao, T. Zhang, Z. Ying, X. Liu. Prospects for Plant-Based Meat: Current Standing, Consumer Perceptions, and Shifting Trends. Foods **11(23**), 3770 (2022).

4. M. Yang, M.N.H. Reza, Q. Yang, A. Al Mamun, N. Hayat. Modelling the mass consumption potential of Plant-Based Meat: Evidence from an emerging economy. Heliyon **10(2)**, e24273 (2024).

5. A. Chopra, J. Jagose, A. Pandey. Health is wealth- eating for tomorrow: factors influencing purchase intention of plant-based diets in India. Cogent Bus. Manag. **12(1)** (2024).

6. Raptou, A. Tsiami, G. Negro, V. Ghuriani, P. Baweja, S. Smaoui, T. Varzakas. Gen Z's Willingness to Adopt Plant-Based Diets: Empirical Evidence from Greece, India and UK (2024).

7. V. Sharma, A. Singh & M. Thakur. Millets: Biology, Classification & Applications. In: M. Thakur (ed.), *Millets: The Multi-Cereal Paradigm for Food Sustainability.* World Sustainability Series, Springer, Cham (2024).

8. D. Balli, M. Bellumori, A. Masoni, M. Moretta, E. Palchetti, B. Bertaccini, N. Mulinacci, M. Innocenti. Proso Millet as an Alternative Source of Starch and Phenolic Compounds. Molecules **28(17)** (2023).

9. A. Mateen, G. Singh. Evaluating the potential of millets with soy protein isolate in high moisture extrusion. Food Res. Int. **173,** 113395 (2023).

10. B. Ayeleso, K. Ramachela, E. Mukwevho. Therapeutic potentials of sweet potato. Trop. J. Pharm. Res. **15(12),** 2751–2761 (2017).

11. FAO. Food energy – Methods of analysis and conversion factors. FAO Food Nutr. Pap. 77, Rome (2003).

12. AOAC. Standard official methods of analysis. AOAC Int. (2005).