Electronic Journal of University of Aden for Basic and Applied Sciences

EJUA-BA Vol. 6 No. 2 (2025)

https://doi.org/10.47372/ejua-ba.2025.2.445

ISSN: 2708-0684

RESEARCH ARTICLE

MANUFACTURING AND DEVELOPMENT OF TOMATO SAUCE ENRICHED WITH DIETARY FIBER TO IMPROVE NUTRITIONAL VALUE AND SENSORY QUALITY

Mohammed Alsebaeai[1,*], Nabil Aldoubai[1], Laila Naji[1], Fadah Alwarafi[1], Omar Al-Faqih[1], Raghad Qahtan[1], Zakarya Mashrah[1], Noor Al-Sanea[1], Weam Al-Sanea[1]

[1] *Dept. of Food Science and Technology, Faculty of Agriculture and food science, Ibb University, Ibb, Yemen*

***Corresponding author: Mohammed Alsebaeai1; E-mail: malsobaee22@gmail.com; Phone: 774488038**

Received: 21 April 2024 / Accepted: 12 May 2025 / Published online: 30 June 2025

Abstract

This study aimed to manufacture and develop tomato sauce fortified with dietary fiber using wheat bran and flaxseed, in order to improve its nutritional value and sensory quality. The sauce was manufactured in the laboratories of the Department of Food Science and Technology in Yemen, where fiber was added in different concentration (0.5%, 1%, 2%), then chemical, sensory and microbial tests were conducted according to the approved standard methods. The results showed that the additives did not significantly affect the percentage of total solids, but the sample fortified by 0.5% flax seeds showed a significant difference in pH. The effect on color was minor at low percentages, but high percentages reduced organoleptic ratings while flavor was not affected at low ratios, while the addition of 2% flaxseed improved it. Wheat bran up to 2% did not affect the texture, while flaxseed above 0.5% affected it slightly. Wheat bran also did not negatively affect appearance, while flaxseed at 2% made minor changes. This study recommends that in order to balance health benefits and sensory quality, it is preferable to use wheat bran in moderation, and to use flaxseed to no more than 1% to maintain the appearance and attractive texture of the sauce.

Keywords: Sauce, Tomato, Wheat bran, Flaxseed, Development.

1. Introduction

Tomato sauce is a staple food in many diets around the world, boasting high nutritional value and antioxidant compounds such as lycopene, which has been linked to a reduced risk of heart disease and certain cancers[1]. However, most commercial tomato sauces lack dietary fiber, which plays a key role in promoting digestive health and reducing the risk of chronic diseases such as type 2 diabetes, obesity, and heart disease [2].

The growing interest in enhancing the nutritional and functional quality of food products has led to the exploration of dietary fibers and by-products as valuable ingredients in tomato-based formulations. Recent studies have demonstrated the potential of various fiber sources to improve the health profile of tomato sauces while promoting sustainability. Rivas et al. [3] highlighted the use of dietary fiber from wine lees as a sugar substitute, showing improved nutritional properties, increased antioxidant activity, and enhanced technological traits, particularly in formulations with 25% sugar reduction. Similarly,

Herrera et al. [4] emphasized the nutritional value of tomato fiber derived from tomato peels, which is rich in insoluble dietary fiber and beneficial macronutrients, supporting its use in functional foods. Tagliamonte et al. [5] demonstrated that enriching tomato sauces with tomato pomace significantly increased levels of carotenoids, α-tocopherol, and antioxidant capacity, with the 100% pomace-based formulation showing enhanced nutrient bioaccessibility. Conversely, Tomas et al. [6] found that adding inulin reduced phenolic content and antioxidant activity, although it may contribute to the preservation of fruit-specific compounds. Collectively, these findings support the incorporation of various dietary fibers and by-products to enhance the nutritional quality, sustainability, and functional benefits of tomato-based products. In addition to nutritional and sensory considerations, food safety and shelf stability are critical

for the successful commercialization of any food product. Research by Alsebaeai et al. [7] emphasized the importance of appropriate packaging materials in prolonging the shelf life and maintaining the quality of green chilli powder, underlining how storage conditions directly impact product stability. Furthermore, the study by Mohammed et al. [8] evaluating the hygienic quality of yoghurt sold in local markets in Sana'a City, Yemen, highlights the pressing need for stringent hygienic practices in food production and handling to protect public health.

Enriching tomato sauce with dietary fiber is a modern approach to improving the nutritional value of this product without compromising its sensory quality. Dietary fiber, particularly soluble fiber such as oat fiber, pectin, and psyllium fiber, helps improve gut health, lower cholesterol levels, and promote feelings of fullnesss [9]. This research aims to manufacture and develop a tomato sauce enriched with dietary fiber from natural sources such as wheat bran, apple fiber, or flaxseed, while evaluating the effect of this addition on the chemical, physical, and sensory properties of the final product. The product's stability during storage will be analyzed, and consumer acceptance of this innovative sauce will be studied. This study is expected to contribute to the introduction of a healthy, functional product that meets the needs of health-conscious consumers and promotes the development of fortified food products. The aim of this research was to produce a fiber-enriched tomato sauce using natural sources. It also aimed to study the effect of adding fiber on the physical and chemical properties of the sauce, in addition to analyzing the sensory quality of the product in terms of color, texture, taste, and aroma.

2. Material and methods

2.1. Samples collection

2.2. Ingredients used:

Tomatoes were purchased from the local market and used to prepare the sauce. Also, wheat bran and flax seeds were also purchased from the local market in Ibb, Yemen.

2.3. Experimental design:

Preparing three samples of tomato sauce with different percentages of fiber (wheat bran or flaxseed) (0.5%, 1%, 2%).

2.4. Fiber-Enriched Tomato Sauce processing

Making fiber-enriched tomato sauce requires meticulous steps to ensure quality, consistency, and palatability. The following are the basic manufacturing steps:

2.4.1. Selection and Preparation of Raw Materials

Fresh, ripe, and blemish-free tomatoes were selected. Source of dietary fiber, such as wheat bran and flax fiber, was provided. Additional ingredients, such as salt, were prepared.

2.4.2. Washing and Sterilization

The tomatoes were thoroughly washed to remove dirt and pesticides using clean, sterilized water.

2.4.3. Blanching and Softening

The tomatoes were heated at 80-90°C for 3-5 minutes to facilitate peeling and improve texture. Blanching helps reduce microbes and increase the concentration of lycopene, an important antioxidant.

2.4.4. Peeling and Grinding

The skins and seeds were removed using a cheesecloth sieve. The tomatoes were then ground to a smooth, homogeneous paste using an industrial blender.

2.4.5. Adding Fiber and Other Ingredients

The tomato paste was mixed with dietary fiber in the specified proportions (0.5%, 1%, 2%). Salt was also added in the optimal proportions.

2.4.6. Cooking and Concentration

The sauce was heated at 90-100°C for 30-60 minutes to reduce the water content and thicken the consistency, stirring continuously to prevent burning and ensure the mixture was homogeneous.

2.4.7. Packaging

The glass jars were sterilized before filling with boiling water for half an hour. The hot sauce was filled directly into the jars and sealed to ensure preservation.

2.4.8. Sterilizing the Finished Product

The glass jars were left to boil for 15-30 minutes.

2.4.9. Cooling and Storage

The jars (upside down) were gradually cooled to room temperature to prevent condensation inside the jars. They were stored in a cool, dry place away from direct sunlight to maintain quality.

2.5. Chemical Analysis:

The following tests, such as acidity, moisture content, solids content, and pH, were determined according to AOAC [10].

2.6. Sensory Analysis:

Taste tests were conducted to evaluate texture, color, taste, and aroma using a specialized panel using the 9-point Hedonic scale.

2.7. Microbiological Tests:

Total bacterial and mold counts were determined by pouring from plates.

2.8. Data Analysis:

The data collected were subjected to statistical analysis using one-way analysis of variance and the means were compared by the least significant difference (LSD) test by using SPSS.26.0.

3. Result and Discussion

3.1. The effect of fiber fortification on the physicochemical characteristics in tomato sauce

3.1.1. The effect of fiber fortification on the moisture content in sauce samples

Table 1 shows that the addition of wheat bran leads to a gradual decrease in moisture content as the percentage of addition increases. The standard sample (unfortified tomato sauce) recorded the highest moisture content of 74.91%, while this percentage decreased to 74.45% with the addition of 0.5% wheat bran, and to 73.35% with the addition of 1% wheat bran. The percentage reached its lowest level with the addition of 2% wheat bran, reaching 72.42%. This gradual decrease in moisture content is attributed to the ability of wheat bran to absorb water, which reduces the free water content of the sauce. As for the samples enriched with flaxseed, mixed results were observed. The moisture content of the 0.5% flaxseed sample decreased to 72.63%, but increased again with the addition of 1% flaxseed, reaching 74.55%. However, the moisture content decreased significantly with the addition of 2% flaxseed, reaching 70.65%, the lowest moisture content recorded in the study. This discrepancy may be explained by the fact that flaxseed contains natural oils that may affect water absorption, which may explain the higher moisture content at 1%. Increasing the addition percentage to 2% resulted in a decrease in moisture due to the fibers absorbing water and preventing its retention within the sauce.

3.1.2. The effect of fiber fortification on the solids content in sauce samples

The results in Table 1 showed that adding 0.5% wheat bran resulted in a slight decrease in the total soluble solids content to 27.66% compared to the original tomato sauce, which was 28%. Increasing the wheat bran content to 1% and 2% increased the total solids content to 28.3% and 28%, respectively, suggesting that the negative effect of adding bran on solubility may be limited at higher concentrations. This may be due to the absorption of liquid by the fibers in the bran, which reduces the initial solubility of some of the solids. However, as the amount increases, the bran becomes part of the solid structure itself and therefore does not affect the total soluble solids value. No significant differences were observed when adding flaxseed at 0.5%, 1%, and 2%, with the total solids content remaining at 28% in all cases. This suggests that flaxseeds do not significantly affect the soluble solids concentration of the sauce. This is probably because most of the flaxseed components are insoluble in water, or form a gel that absorbs water but does not change the soluble solids content. It is also possible that the fiber and gelatinous compounds in flaxseeds do not interact with water and solids in the same way as wheat bran.

3.1.1. The effect of fiber fortification on the pH in sauce samples

The results in Table 1 indicate that the addition of wheat bran resulted in a slight decrease in pH compared to the unfortified standard sauce, dropping from 4.42 to 4.25 when 0.5% wheat bran was added. As the percentage of wheat bran increased to 2%, the pH rose slightly to 4.30. This slight decrease is attributed to the ability of the dietary fiber in wheat bran to absorb some of the organic acids in the sauce, slightly modifying the acidity.

Table 1: The effect of fiber fortification on the Chemical characteristics in sauce samples

S.N	Samples	Chemical characteristics			
		Moisture (M±SD)	Total solids (M±SD)	Ph (M±SD)	Acidity (M±SD)
	Tomato sauce	74.91±1.00^{a}	.28±1.00^{a}	4.42±0.02^{a}	1.53±0.04^{a}
	Tomato sauce enriched with 0·5% wheat bran	74.45±0.12^{a}	27.66±0.57^{b}	4.25±0.04^{a}	1.53±0.02^{b}
	Tomato sauce enriched with 1% wheat bran	73.35±0.39^{a}	28.3±0.57^{b}	4.28±0.03^{a}	1.54±0.17^{a}
	Tomato sauce enriched with 2% wheat bran	72.42±0.29^{a}	28±0.23^{b}	4.30±0.040^{a}	1.51±0.34^{b}
	Tomato sauce enriched with 0·5% flax seeds	72.62±0.30^{a}	28±1.00^{b}	4.44±0.04^{b}	1.05±0.04^{a}
	Tomato sauce enriched with 1% flax seeds	74.55±0.39^{a}	28±0.34^{b}	4.48±0.07^{a}	1.26±0.04^{a}
	Tomato sauce enriched with 2% flax seeds	70.64±0.58^{a}	28±2.00^{b}	4.51±0.08^{a}	1.55±0.04^{b}

*Mean ± Standard deviations (n = 3).

Means in the same column with different upper-case letters are significantly different ($P < 0.05$).

However, these changes are still within the acceptable range, indicating that wheat bran does not significantly affect the natural acidity of the sauce. Conversely, the addition of flaxseeds resulted in a significant increase in pH. The pH increased from 4.42 in the standard sample to 4.45 when 0.5% flaxseeds were added, and continued to rise to 4.52 when 2% flaxseeds were added. This increase is due to the alkaline nature of flaxseeds, which contain fatty substances and can react with the acids in the sauce, reducing the acidity level.

3.1.2. The effect of fiber fortification on the acidity in sauce samples

The results in Table 1 showed that acidity did not change significantly when wheat bran was added. The standard (unfortified) sauce recorded an acidity of 1.5367% ± 0.04041a, while values ranged from 1.5300% ± 0.02000b with the addition of 0.5% wheat bran to 1.5400% ± 0.01732a with 1% wheat bran. Acidity decreased slightly to 1.5100% ± 0.03464b with the addition of 2% wheat bran. This slight decrease in acidity with the increase in wheat bran content can be explained by its ability to absorb some organic acids or interact with acidic compounds in the sauce, reducing their actual concentration. As for the samples fortified with flaxseed, they showed a more pronounced decrease in acidity. The sample enriched with 0.5% flaxseed recorded the lowest acidity, 1.0533% ± 0.04163a, while the acidity increased to 1.2600% ± 0.04359a when 1% flaxseed was added. This significant decrease suggests that flaxseed may have a greater ability to neutralize acidity or interact with organic acids than wheat bran. This may be due to the fact that flaxseed contains fatty compounds and active substances that can affect the acid concentration in the sauce.

3.2. The effect of fiber fortification on the Microbial analysis in sauce samples.

3.2.1. The effect of fiber fortification on the Microbial analysis (Total number of bacteria) in sauce samples.

The results in Figure 1 indicate that adding 0.5% wheat bran reduced the bacterial count from 58 CFU/g in the standard sample to 34 CFU/g, indicating a slight antimicrobial effect. However, when increasing the wheat bran content to 1%, the bacterial count returned to the same level as the standard sample (58 CFU/g), indicating that the antibacterial effect was not sustained at this content. In contrast, increasing the wheat bran content to 2% completely eliminated the bacterial presence (0 CFU/g). This potential effect may be explained by the high content of insoluble fiber, which may affect the microbial environment by altering the properties of the sauce, such as water content or the bioavailability of nutrients to bacteria.

For the flaxseed-enriched samples, as shown in Figure A, the effect was more pronounced, with no bacterial growth (0 CFU/g) detected in the samples containing 0.5% and 1% flaxseed. This effect may be due to the antimicrobial compounds present in flaxseed, such as phenols and lignans, which possess antibacterial properties[11]. However, the sample enriched with 2% flaxseed showed similar bacterial levels to the standard sample (58 CFU/g), suggesting the potential for complex interactions between sauce components at high levels, which may affect the effectiveness of the antibacterial compounds.

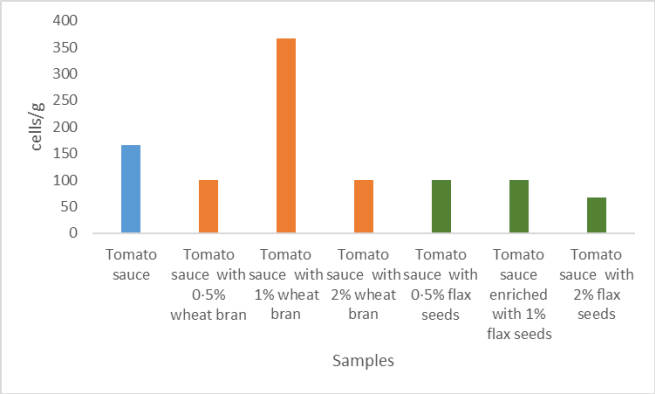

Fig. 1: The effect of fiber fortification on the Total number of bacteria in sauce samples.

3.2.2. The effect of fiber fortification on the Microbial analysis (Total number of fungi) in sauce samples.

The results in Table 1 indicate that adding 0.5% wheat bran did not affect the total fungal count compared to the unfortified sauce sample, which remained stable at 18 fungi/g. However, when the wheat bran percentage was increased to 1%, the total fungal count increased to 45 fungi/g, while it decreased to 30 fungi/g when adding 2% wheat bran. This increase at 1% may be explained by the fact that wheat bran may provide a suitable environment for fungal growth due to its content of certain organic compounds that fungi can exploit as a food source. However, the decrease at 2% may be due to the effect of the high fiber content on reducing the free moisture available for fungal growth, or to the presence of antifungal compounds in the bran that operate at this percentage. In the samples fortified with flaxseed, the changes in fungal growth were more pronounced. At 0.5% flaxseed, the total fungal count increased to 31 fungi/g, indicating that this ratio did not significantly inhibit fungi. With an increase in the flaxseed ratio to 1%, the count increased significantly to 58 fungi/g, indicating that flaxseed at this ratio may provide a supportive environment for fungal growth, possibly due to the oils or nutrients it contains that help stimulate the growth of some fungi. However, the sample containing 2% flaxseed showed a decrease in the count to 17 fungi/g, suggesting that higher flaxseed concentrations

may contain compounds with an inhibitory effect on fungi, such as phenolics or lignans, which are known for their antimicrobial and antifungal properties.

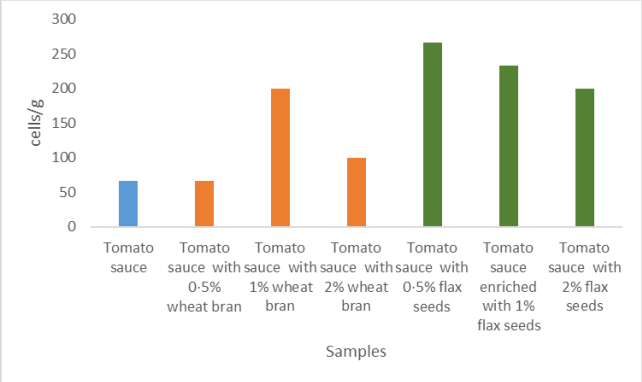

Fig. 2: The effect of fiber fortification on Total number of fungi in sauce samples.

3.3. The effect of fiber fortification on the sensory evaluation in sauce samples

This study examines the sensory evaluation of several types of tomato sauce, both plain and enriched with different proportions of wheat bran and flaxseed, based on four main criteria: color, flavor (taste), texture, and overall appearance.

3.3.1. The effect of fiber fortification on the sensory evaluation (color) in sauce samples

It was observed that most samples received relatively high ratings, ranging from 6.67 to 7.67, indicating good acceptance by the evaluators as presented in fig 3. Tomato sauce enriched with 1% wheat bran scored the highest rating (7.67), indicating that this ratio improved or better preserved the color. In contrast, slightly lower ratings were observed for samples enriched with flaxseed, particularly at 1% and 2%, which received the lowest rating (6.67).

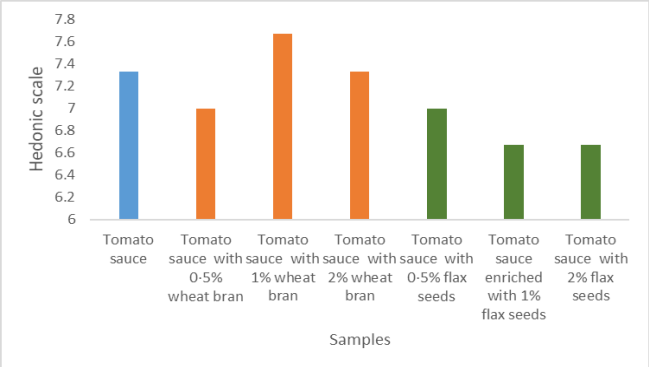

Fig. 3: The effect of fiber fortification on the sensory evaluation (color) in sauce samples

3.3.2. The effect of fiber fortification on the sensory evaluation (Flavor) in sauce samples

In terms of flavor, there were significant variations between samples. The original tomato sauce and the samples enriched with 0.5% wheat bran or flaxseed, as well as 1% wheat bran, all received the same rating (5.67), demonstrating moderate flavor acceptance without significant effect of additives at these low levels. In contrast, a significant improvement in flavor was observed with the addition of 2% flaxseed, with this sample receiving the highest rating (7.33), indicating that this ratio produces a more desirable flavor.

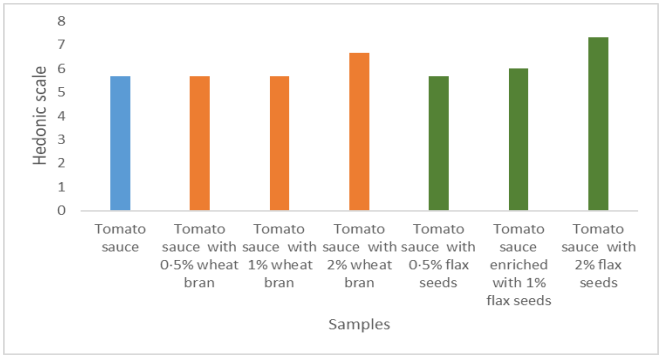

Fig. 4: The effect of fiber fortification on Flavor in sauce samples

3.3.3. The effect of fiber fortification on the sensory evaluation (Texture) in sauce samples

Regarding texture and consistency, the results showed relative stability, with ratings ranging from 6.67 to 7.33. The original tomato sauce and the samples enriched with 1% and 2% wheat bran received the highest texture rating (7.33), indicating that the wheat bran contributed to improving or maintaining the texture. Flaxseed samples, particularly at 1% and 2% concentrations, received a lower rating (6.67), which may indicate the effect of this addition on the smoothness or thickness of the sauce.

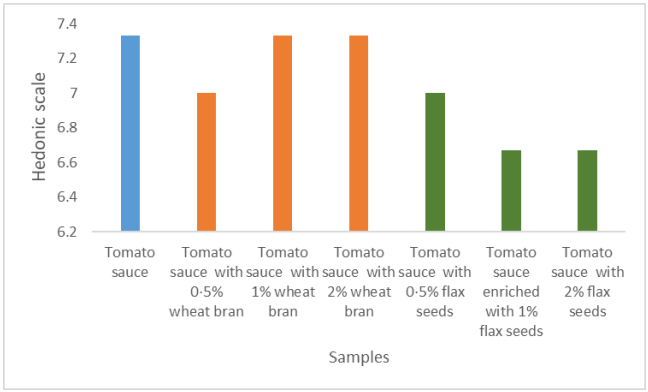

Fig. 5: The effect of fiber fortification on Texture in sauce samples

3.3.4. The effect of fiber fortification on the sensory evaluation (appearances) in sauce samples

As for overall appearance, ratings ranged from 6.33 to 7.33. The addition of wheat bran at 0.5% and 2% concentrations yielded the highest rating (7.33), reflecting the role of this addition in improving the product's appearance. Conversely, tomato sauce fortified with 2% flaxseeds received the lowest rating (6.33),

which may be due to a change in color or consistency due to the concentration of the seeds.

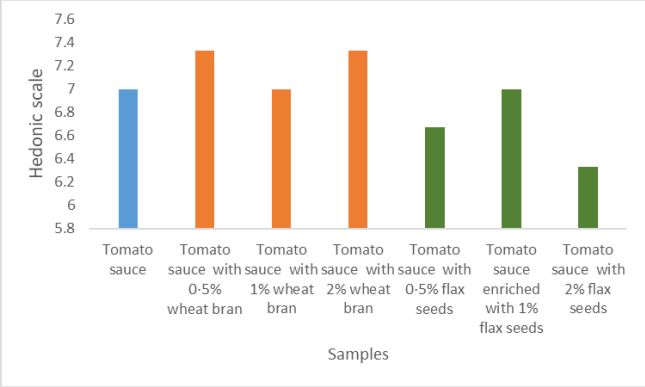

Fig. 6: The effect of fiber fortification on appearances in sauce samples

4. Conclusion

The study results indicate that enriching tomato sauce with wheat bran or flax seeds affects some of the product's physical and sensory properties. Significant differences were observed in moisture content when using 2% wheat bran or flax seeds, while 0.5% wheat bran affected the solids content, with flax seeds showing no clear effect. Acidity was also significantly reduced when adding 0.5% flax seeds, while the effects of wheat bran were minor. Regarding color, low additives did not significantly affect the flavor, while high levels may lead to a decrease in the sensory evaluation of color, requiring caution. Regarding flavor, 2% flax seeds improved the sensory evaluation, and wheat bran also showed a positive effect. Texture was unaffected by the addition of wheat bran up to 2%, while flax seeds above 0.5% may cause minor changes. As for appearance, it remained good with wheat bran and may even improve, while 2% flaxseed may have a slight impact, so it's best not to exceed 1%. Accordingly, it's recommended to use wheat bran at up to 2% without adverse effects, while 1% flaxseed may be used to achieve nutritional benefits without compromising the product's sensory quality.

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مقالة بحثية

تصنيع وتطوير صلصة طماطم غنية بالألياف الغذائية لتحسين القيمة الغذائية والجودة الحسية

محمد السباعي[1]*، نبيل الدبعي[1] ، ليلى ناجي[1]، افادة الورافي[1]، عمر الفقية[1]، رغد قحطان[1]، زكريا مشرح[1]، نور الصانع[1]، وئام الصانع[1]

[1] قسم علوم وتكنولوجيا الأغذية، كلية الزراعة وعلوم الأغذية، جامعة اب، اب، اليمن

* الباحث الممثّل: محمد السباعي؛ البريد الالكتروني: malsobaee22@gmail.com؛ تلفون: 774488038

استلم في: 21 ابريل 2025 / قبل في: 12 مايو 2025 / نشر في 30 يونيو 2025

المُلخّص

هدفت هذه الدراسة إلى تصنيع وتطوير صلصة طماطم مدعمة بالألياف الغذائية باستخدام نخالة القمح وبذور الكتان، وذلك لتحسين قيمتها الغذائية وجودتها الحسية. تم تصنيع الصلصة في معامل قسم علوم وتكنولوجيا الأغذية باليمن، حيث أضيفت الألياف بنسب مختلفة (0.5%، 1%، 2%)، ثم أجريت الفحوصات الكيميائية والحسية والميكروبية وفق الطرق القياسية المعتمدة. أظهرت النتائج عدم تاثير الإضافات بشكل جوهري على نسبة المواد الصلبة، لكن العينة المدعمة بـ 0.5% بذور كتان أظهرت فرقًا معنويًا في نسبة الحموضة. وكذلك التأثير على اللون كان طفيفًا عند النسب المنخفضة، لكن النسب العالية قللت من التقييم الحسي بينما لم تتأثر النكهة عند النسب المنخفضة، بينما أدت إضافة 2% بذور كتان إلى تحسينها. نخالة القمح حتى 2% لم تؤثر على القوام، بينما بذور الكتان بنسبة أعلى من 0.5% أثرت عليه قليلاً. وكذلك لم تؤثر نخالة القمح سلبًا على المظهر، في حين أن بذور الكتان بنسبة 2% أحدثت تغييرات طفيفة. توصي هذه الدراسة من اجل تحقيق توازن بين الفوائد الصحية والجودة الحسية، يفضل استخدام نخالة القمح بنسبة معتدلة، واستخدام بذور الكتان بنسبة لا تتجاوز 1% للحفاظ على مظهر الصلصة وقوامها الجذاب.

الكلمات المفتاحية: صلصة، طماطم، نخالة القمح، بذور الكتان، تطوير.

How to cite this article:

M. Alsebaeai, N. Aldoubai, L. Naji, F. Alwarafi, O. Al-Faqih, R. Qahtan, Z. Mashrah, N. Al-Sanea, W. Al-Sanea, "MANUFACTURING AND DEVELOPMENT OF TOMATO SAUCE ENRICHED WITH DIETARY FIBER TO IMPROVE NUTRITIONAL VALUE AND SENSORY QUALITY", *Electron. J. Univ. Aden Basic Appl. Sci.*, vol. 6, no. 2, pp. 104-110, June. 2025. DOI: https://doi.org/10.47372/ejua-ba.2025.2.445