COMPARATIVE STUDIES ON NUTRITIONAL AND PESTICIDES RESIDUE IN ORGANIC AND CONVENTIONALLY GROWN BLACK WHEAT IN THE SHEKHAWATI REGION OF RAJASTHAN

[1]Surbhi Soni
[1]Research scholar, Mody university of Science and Technology
surbhisoni499@gmail.com

Abstract

Objectives: This present study aims to compare the nutritional composition, levels of pesticide residues, and environmental impact of organic compared with conventionally grown black wheat in the semi-arid Shekhawati region of Rajasthan.

Methods: A samples of black wheat collected from organic and conventional farming were taken from two different regions namely:-Conventinal sample taken from Chainpura region and organic sample taken from Kolida region. Analysis of nutritional parameters includes estimation of protein, fat, fiber, zinc, and calcium. Pesticide residues were quantified by both GC-MS and LC-MS/MS techniques. Soil and water quality also were measured to assess the environmental impacts. Various statistical analyses, such as t-test and PCA, were made to determine significance and find out the clustering patterns.

Results: Organic black wheat had higher contents of fibers (8.38%) and zinc (4.79 mg/100g) but had lower contents of proteins (12.96%) and fats (0.73%) than conventional samples. Interestingly, the organic samples did not have any pesticide residues, whereas residues in conventional samples were higher than the maximum allowed residue limit. Environmental indicators showed that organic farming practices have lesser soil salinity, less contamination, and greater nutrient retention compared to conventional farming.

Conclusion: Organic black wheat reduces pesticide residue content and increases soil health, thus bringing environmental as well as health benefits. Though, it lacks in increasing its protein content as per market demands. The present investigation throws light on the possibility of organic farming in promoting the concept of sustainable agriculture despite difficult agro-climatic conditions.

Keywords: Black wheat, Organic farming, Pesticide residues, Nutritional composition, Shekhawati region, Sustainable agriculture.

1. Introduction

Agriculture is the backbone of India's economy, providing a major source of livelihood and sustenance for its vast population [1]. Among the many crops grown in the country, wheat is an important staple food grain [2]. Recently, black wheat (Triticum aestivum var. nigrospica), with its dark pigmentation and unique nutritional characteristics, has gained attention as a potential substitute for conventional wheat varieties. It is a type of flavonoid, known as anthocyanin, that is extremely rich and possesses powerful antioxidant properties, thereby reducing the risk of chronic diseases, such as diabetes, cardiovascular diseases, and some cancers. Consequently, black wheat is viewed increasingly as a nutritionally superior option with great potential to be a health-promoting option [3].

Due to organic farming practices, this crop has gained more attraction, as organic systems take importance on health, diversity and an environmental sustainability by using some biochemicals such as bio-fertilizers and compost avoiding synthetic pesticides and fertilizers [4]. The Shekhawati region of Rajasthan makes agriculture in that region challenging through these reasons, such as shifting extremes in temperature and low annual rainfall on sandy soils, thus this organic cultivation gives significant importance [5]. Despite these adversities, the region's agricultural legacy is robust, and the introduction of black wheat into its cropping systems provides fertile ground for its assessment in terms of adaptability and performance under organic versus conventional farming systems [6].

The production techniques of black wheat affect its quality, safety, and marketability. Organic farming practices are often advocated to yield healthier crops free from residues of toxic pesticides, whereas the conventional farming techniques have opted for maximizing yield using synthetic fertilizers and pesticides [7]. The different techniques have also sparked controversy on which one is better than the other in terms of pesticide residues' safety and nutritional crop quality. The environmental and health impacts of synthetic pesticides in conventional agriculture are well known, with possible interference in soil ecosystems, water sources contamination, and consumer health implications [8]. On the other hand, organic systems may suffer from residual contamination effects arising from past agricultural practices or drift from adjacent conventional farms.

Given the increasing global focus on sustainable agriculture and food safety, an in- depth comparative nutritional analysis and pesticide residue quantification of black wheat

cultivated using organic and conventional means assumes timely and high impact significance [9]. Such studies are important not only for trade-offs between these farming systems but also for region-specific insights into the impact of environmental conditions and agronomic practices on the crop's phenolic composition, antioxidant activity, and overall quality. Within this backdrop, this research would examine the potential of black wheat as a sustainable crop to be grown in Shekhawati and elsewhere to contribute to the discourse of sustainable agriculture and food safety. Park, et al. (2015)[10] compared the effect of organic versus conventional farming on the functional and nutritional attributes of wheat. Organically grown wheat, the study found, was characterized by a higher content of dietary fiber but a lower antioxidant capacity than conventionally grown wheat. Knuth, et al. (2024)[11] assessed the occurrence of pesticide residues in soils under organic and conventional management within different European countries. Results were obtained, indicating that fields under conventional management contain more and higher concentrations of pesticide residues than those under organic management. This has emphasized the role farming practices play in determining levels of soil contamination.

2. Methodology

2.1 Study Area and Sample Collection

This survey was conducted in the semi-arid region of Shekhawati, Rajasthan covering two regions namely:-: Chainpura and Kolida. This region has less congenial agricultural conditions; nevertheless, the selection of the region gave an excellent chance to test the resilience of black wheat under these situations. Farms that cultivate the black wheat organically, that is, for a period of at least three consecutive years, were considered with the intention of avoiding contaminated organic practices. Certified organic farms were selected on the basis of their compliance with established organic farming protocols. Similarly, conventional farms using synthetic fertilizers and pesticides were selected to represent conventional farming practices. Ten replicates of each farming type (organic and conventional) were collected, resulting in a total of 20 samples, which ensured statistical robustness in the analysis.

2.2 Sample Preparation

Wheat samples collected underwent thorough cleaning for the removal of debris and contaminants. The samples were dried air at room temperature, hence keeping them intact as received. They were then ground to fine powder form using laboratory-grade grinders, thereby giving them a standard texture and quality in which subsequent analysis would take place. In this preparation, standardization of samples and the elimination of variability during the analytical process were attained.

2.3 Nutritional Analysis

The proximate and mineral composition analyses of black wheat were conducted for nutritional evaluations. Proximate compositions analyzed the important parameters such as moisture content, ash content, proteins, fats, carbohydrates, and fibre. Protein was estimated on a Kjeldahl basis, while fats extracted using Soxhlet method. Carbohydrates found by difference and fibre from standard procedures. In addition, the determination of mineral content was made by atomic absorption spectroscopy (AAS), wherein essential elements like iron, zinc, calcium, and magnesium are targeted. The vitamin profiling involved in this analysis included B-complex vitamins and vitamin E determination by high-performance liquid chromatography (HPLC).

2.4 Pesticide Residue Analysis

The safety of black wheat consumption was assessed through the analysis of pesticide residues by employing the QuEChERS method, which is one of the most efficient techniques in extracting residues from agricultural samples. Organochlorine and organophosphate pesticides were analyzed by gas chromatography-mass spectrometry (GC-MS), while polar pesticides were assessed by liquid chromatography-mass spectrometry/mass spectrometry (LC-MS/MS). The LOD was set in line with international standards and includes guidelines from Codex Alimentarius to ensure high reliability in the results produced.

2.5 Statistical Analysis

It uses comprehensive statistical methods for data comparison. Student's t-test was applied for assessing the significance of the mean values of nutritional parameters and pesticide residues between organic and conventional samples. Multivariate techniques, such as Principal Component Analysis (PCA), have been used to observe any clustering pattern according to the farming practices. Further correlation analysis has been conducted between the levels of pesticide residue and nutritional parameters.

3. Results

S. no.	Nutritional Parameter	Organic Black	Conventional Black
		Wheat	**Wheat**
	Chemical analysis		
1.	Protein (%)	12.96 g/100g	13.58
2.	Energy	350.77	354.26
3.	Fiber (%)	8.38	7.26
4.	Moisture	11.23	11.64
5.	Fat	0.73	1.62
	Natural colour		
6.	Carotenoids	Absent	Absent
	Antioxidants		
7.	Butylated Hydroxyanisole (BHA)	BLQ (LOQ-20.0)	BLQ (LOQ-20.0)
8.	Butylated Hydroxytoluene (BHT)	BLQ (LOQ-20.0)	BLQ (LOQ-20.0)
9.	Tert Butyl Hydroxyquinone (TBHQ)	BLQ (LOQ-20.0)	BLQ (LOQ-20.0)
	Minerals		
10.	Calcium (mg/100g)	62.99	66.44
11.	Zinc (mg/100g)	4.79	4.70

Comparing organic and conventional black wheat, it was established that organic wheat had lesser amounts of protein (12.96% vs. 13.58%) and fats (0.73% vs. 1.62%) but higher amounts of fibers (8.38% vs. 7.26%) and zinc (4.79 mg vs. 4.70 mg). Both kinds were also shown to have equal levels of energy, with the former yielding 350.77 kcal and the latter, 354.26 kcal. Organic wheat also contains slightly less water (11.23% vs. 11.64%) and calcium (62.99 mg vs. 66.44 mg). Neither variety contains carotenoids or detectable levels of antioxidants. In general, the organic variety contains more fibre and zinc, while conventional contains slightly more protein, calcium, and fat.

		Organic Cultivation	**Conventional**

S.No.	Parameter		Cultivation
1	Soil pH	8.2	8.23
2	Electrical Conductivity (dS/m)	709	913
3	Turbidity	2.1	3.05
4	Calculm (as Ca)	36.5	30.16
5	Chloride	42.07	124.39
6	Fluoride	*BLQ(**LOQ 0.20)	0.17
7	Free Residual Chlorine	*BLQ(**LOQ 4.2)	*BLQ(**LOQ - 0.2)
8	Magnesium (as Mg)	11.55	6.73
9	Nitrate (as NO3)	4.34	15
10	Sulphate (as SO4)	10.22	13.92
11	Total Alkalinity (as CaCO3)	192	140
12	Total Dissolved Solids	384	594
13	Total Hardness (CaCO3)	138.6	102.96
14	Total Suspended Solids	*BLQ(**LOQ - 5.0)	13
15	Sodium	70.5	158.02
16	Potassium	4.07	3.19
17	Sulphide	*BLQ(**LOQ 0.05)	*BLQ(**LOQ - 0.05)
18	Ammonia	*BLQ(**LOQ- 0.3)	*BLQ(**LOQ- 0.3)

A comparison table of organic and conventional farming has been prepared using various parameters of soil and water quality. Organic farming has been reported with more favorable environmental indicators as a lower value for electrical conductivity (709.0 dS/m vs. 913.0 dS/m), turbidity (2.10 vs. 3.05), and chloride content (42.07 vs. 124.39). It also manifests lower nitrates (4.34 vs. 15.0) and sodium concentrations (70.50 vs. 158.02), indicating lower chemical residues and soil salinity for organic methods. Organic production has more calcium (36.50 vs. 30.16), magnesium (11.55 vs. 6.73), and potassium (4.07 vs. 3.19) content, thereby showing better nutrient concentration and soil fertility. Lower total dissolved solids (384.0 vs. 594.0) and total alkalinity (192.0 vs. 140.0) also show that organic farming is moreenvironmentally sound. Parameters such as free residual chlorine, sulphide, and ammonia remain in BLQ in both the systems. These results depict the environmental advantages of organically cultivated crops, which include the maintenance of the health of soil and prevention of chemical contaminants.

S. no.	Pesticide	Organic Black Wheat (mg/kg)	Conventional Black Wheat (mg/kg)	Maximum Residue Limit (MRL)
1.	Chlorpyrifos	ND	0.06	0.05
2.	Malathion	ND	0.04	0.02
3.	Cypermethrin	ND	0.02	0.01
4.	Glyphosate	ND	0.08	0.05
5.	Total Pesticide Residue	ND	0.2	0.1

The table shows pesticide residue in organic and conventional black wheat cultivation. This comparison highlights a great difference in contamination when comparing the two cultivation models. Organic black wheat carries no detectable levels ND of all pesticides tested as shown in the table. On the other hand, the conventional black wheat has residues of all the pesticides listed above in excess of the MRL, that is, chlorpyrifos (0.06 mg/kg vs. 0.05 MRL), malathion (0.04 mg/kg vs. 0.02 MRL), cypermethrin (0.02 mg/kg vs. 0.01 MRL), and glyphosate (0.08 mg/kg vs. 0.05 MRL). The total pesticide residue in conventional black wheat (0.2 mg/kg) also exceeds the MRL (0.1 mg/kg). These results highlight the safety and environmental benefits of organic farming, as it does not involve harmful chemical inputs, and this ensures that the produced food is safe and health protective to consumers.

Serial no.	Parameter	Chainpura (Sikar)	Kolida (Sikar)
1	Location	Chainpura (Sikar)	Kolida (Sikar)
2	pH	8	8.1

3	Electrical conductivity (EC)	0.14	0.16
4	Organic carbon percentage (%)	0.29	0.32
5	Phosphorus (Kg/hectare)	39	36
6	Potash (Kg/hectare)	390	210
7	Zinc (ppm)	0.39	0.36
8	Iron (ppm)	3.91	5.1
9	Copper (ppm)	0.42	0.4
10	Manganese (ppm)	4.91	3.1
11	Sulphur (ppm)	20	22
12	Bulk density (gm/cc)	1.49	1.37
13	Soil moisture (%)	0.47	1.06
14	Color	Reddish brown	Brown
15	Water holding capacity (%)	40.67	42.52
16	Chromium (kg/ha)	7.35	4.31
17	Soil texture	Sandy loam	Sandy loam
18	Nickel (mg/kg)	13.43	7.21

Table shows the comparison of soil quality parameters at two different locations Chainpura and Kolida in Sikar. The pH levels for both the locations are at par, which is 8 and 8.1. Both of the locations have sandy loam soil texture. Differences lie in other parameters. Kolida has a higher percentage of organic carbon (0.32% vs. 0.29%), iron content (5.1 ppm vs. 3.91 ppm), soil moisture (1.06% vs. 0.47%), and water holding capacity (42.52% vs. 40.67%), thus indicating better fertility and water retention. Chainpura, on the other hand, contains higher amounts of potash (390 kg/ha vs. 210 kg/ha), manganese (4.91 ppm vs. 3.1 ppm), and chromium (7.35 kg/ha vs. 4.31 kg/ha), which might affect crop nutrient availability. Brown color with lower bulk density (1.37 gm/cc versus 1.49 gm/cc) indicated better aeration compared with Chainpura reddish-brown soil. It indicates that the soil conditions were distinct regarding management and fertility potential for both locations.

4. Discussion

The study brings to fore substantial nutritional differences and pesticide residues of black wheat grown organically versus conventionally in the Shekhawati region of Rajasthan. Organic black wheat had higher fiber (8.38% compared with 7.26%) and slightly higher levels of zinc (4.79 mg/100g as compared to 4.70 mg/100g) than its conventional counterpart. Conventional black wheat showed a greater amount of protein content (13.58% as against 12.96%) and fat content (1.62% compared to 0.73%). Interestingly, pesticide residues were not detectable in organic black wheat, although they exceeded the MRL in conventional samples. This corresponds to the study of Park et al. (2015) [13], who found higher dietary fiber in organically grown wheat but lower antioxidant capacity than that of the conventional wheat. These results are consistent and support the general trend that organic farming improves nutritional parameters such as fiber, which is vital for dietary health.

Environmental benefits of organic farming were also found in your study. Comparison of soil and water quality results has been found favorable for the organic farming systems, including low electrical conductivity (709 dS/m vs. 913 dS/m), less turbidity (2.1 vs. 3.05), and low chloride content (42.07 mg/L vs. 124.39 mg/L). These results are consistent with Silva et al. (2023) [14], who reported lower salinity in soils and higher organic carbon content in organic systems. Your study further suggests improved fertility and nutrient availability in soils under organic farming due to the higher concentrations of calcium and magnesium, which are corroborative findings with Geissen et al. (2021) [15].

Nutritional evaluation of black wheat indicated that although the organic samples were poorer in protein and fat content, they provided more fiber and marginally higher levels of zinc, which are dietary essential. The outcome is similar to Barański et al. (2014) [16], which mentioned that organic crops typically have less protein content but more micronutrient levels. However, the lack of carotenoids and detectable antioxidants in both organic and conventional black wheat samples does indicate that nutritional benefits conferred by organic farming are crop-specific.

Overall, your study highlights the safety and environmental benefits of producing organic black wheat, specifically in terms of eliminating pesticide residues and improving soil health. These results are highly significant for promoting sustainable agriculture practices in areas like Shekhawati, where agro-climatic conditions are quite adverse. However, the lower protein content in organic black wheat could be a disadvantage when consumers are concerned with preference and marketability. Future research should look at the refinement of organic farming techniques to improve the protein and antioxidant levels of black wheat, thus gaining an edge over conventional outputs.

5. Conclusion

The study highlights the pros and cons of organic farming versus traditional methods of growing black wheat in the Shekhawati region of Rajasthan. Organic black wheat reflected some environmental benefits and nutritional benefits, such as high fiber content and no presence of pesticide residues, thereby being safer and more environmentally friendly. However, it lacked in proteins and fats compared to its regular counterpart, which might put a dent in its acceptability in the market. Soil and water quality parameters further highlighted the superiority of organic practices, showing a lower contamination level and more fertility.

These findings advocate for the promotion of organic black wheat cultivation in order to emphasize its environmental and health benefits. Further research should be directed at the improvement of protein and antioxidant content in organic black wheat to meet consumer requirements and enhance its competitive position. This work contributes a great deal to the sustainable agriculture discourse, especially in difficult agro-climatic conditions.

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