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Risk Assessment of some Contaminants in Locally and Imported Wheat Grains, their Flour and bakery Products in Egyptian Local Markets

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Abstract

This study examines the extent and types of contamination in locally produced and imported wheat grains, wheat flour and some of their products available in the Egyptian markets. Various analytical methods, including chromatography and spectrometry, were utilized to detect contaminants, with a specific focus on heavy metals (lead, cadmium, mercury, and arsenic), phosphine residues and Ergot (mycotoxin). Additionally, the chemical composition of wheat and wheat flour, including moisture, protein, fat, ash, and total carbohydrate content, was analysed. Minerals levels, such as iron, manganese, zinc, sodium, potassium, magnesium, and copper were also determined. The results were indicated that the tested samples generally conform to safety standards, with levels of heavy metals, phosphine residues and Ergot well below permissible limits. The chemical composition falls within acceptable ranges, ensuring product quality. While nutrient content varies among samples, it generally aligns with nutritional expectations. These findings underscore the significance of implementing rigorous quality control measures in the production of wheat grains and wheat flour to protect public health. This comprehensive assessment enhanced our understanding of contamination risks and quality assurance in these vital food commodities, offering valuable insights for regulators, producers, and consumers in Egypt and beyond.

Key words: Wheat ; Wheat flour ; Contaminations ; Heavy metals ; Phosphine residuals ; Ergot.

1. Introduction

The consumption of wheat and wheat flour is widespread globally, with wheat products forming an integral part of many diets [1]. In Egypt, a country known for its rich agricultural heritage, wheat and wheat flour play a crucial role in the daily lives of millions of people However, concerns have been raised regarding the quality and safety of these staple food items, particularly in relation to potential contamination [2]. Contamination of wheat and wheat flour can occur at various stages, ranging from cultivation and harvesting to processing and storage [3]. It can result from factors such as the use of pesticides, fungicides, mycotoxins, heavy metals, and microbial agents [4].Moreover, the presence of contaminants in both locally produced and imported wheat and wheat flour raises questions about the effectiveness of regulatory measures and quality control practices in the Egyptian local market.

To ensure the accuracy and reliability of the findings, employed rigorous analytical methods. The detection and quantification of various contaminants were conducted using state-of-the-art techniques, including chromatography, and spectrometry [5]. The selected contaminants for analysis encompass a wide range of potential risks to human health and food safety.

Phosphine residuals in wheat and wheat flour have become an area of concern in relation to food safety and human health. Phosphine is commonly used as a fumigant to control pests in stored grain and flour products, but the presence of residual phosphine raises questions about its potential impact on the quality and safety of these essential food items. Studies have shown that phosphine residuals can persist in grain and flour even after fumigation, posing challenges for regulatory bodies and quality control measures [6].

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The levels of phosphine residuals varied depended on several factors, including the fumigation technique, dosage, exposure duration, and storage conditions [7]. Residual phosphine could accumulate in wheat and wheat flour, particularly in the outer layers, and might pose potential health risks when consumed [8]. Therefore, comprehensive investigations were conducted to assess the extent and distribution of phosphine residuals in wheat and wheat flour from different sources and processing stages [9].

Furthermore, the persistence of phosphine residuals, which often used to protect grains and flour products were studied to understand and mitigate their potential risks [10]. Heavy metals in wheat and wheat flour have gained significant attention due to their potential impact on human health. These metals, including lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), could enter the food chain through various sources such as soil contamination, irrigation water, and agricultural practices [11, 12].

Research had showed that heavy metals contamination in wheat and wheat flour varied according to geographical location, farming practices, and post-harvest processing [13,14]. High levels of heavy metals could pose significant health risks, including developmental and neurological disorders, organ damage, and carcinogenic effects [15,16].

Ergot alkaloids (EAs) were mycotoxins produced by different fungi of the *Clavicipitaceae* family, such as *Claviceps purpurea*, *Claviceps paspali*, and *Claviceps fusiformis*, which were prevalent in cereals such as rye, wheat, barley, millet, triticale, and oat. Recent studies had highlighted the importance of rigorous monitoring and control measures to prevent ergot contamination in wheat production [17]. Advances in agricultural practices, such as improved seed selection, cultivation techniques, and post-harvest management, played a crucial role in minimizing the risk of ergot infestation [18]. strict regulatory standards and quality control protocols at various stages of the supply chain contributed to ensuring the safety and integrity of wheat products for consumers worldwide implemented [19]. Therefore, this study aims to assess the quality and safety of locally and imported wheat grains, wheat flour, and their products in the Egyptian local markets by measuring the extent and types of contamination such as heavy metals (lead, cadmium, mercury, and arsenic), phosphine residues and ergot (Mycotoxin).

Materials and Methods:

Materials:

(Samples were collected from various sources, including mills and retail outlets, to provide a comprehensive analysis).

- Wheat grains and Wheat flour (*Triticum aestivum L.*): Samples of Russian, Ukrainian, and Egyptian local wheat and their corresponding flours were obtained from North Cairo Mills and Bakeries Company, Al Kawther Flour Mill, El Salam City, Cairo, Egypt (in February 2022). French wheat was sourced from the Egyptian Holding Company for Silos and Storage, Sawah Square, Hadayek Al-Kobba, Cairo, Egypt (in March 2022).
- Wheat and Wheat flour (Triticum durum): Egyptian hard wheat and their flour were collected from middle Egypt milling in Bani Sweif City, Egypt.
- Wheat Products i.e.: Egyptian Baladi flatbread, Pan bread, Pasta (Elbows), and Baguette bread were sampled from the local market in Cairo, Egypt (in May 2023).

Methods:

Sampling:

Nine representative samples of wheat and wheat flour (500 gm each) were collected separately from selected resources. Control samples were obtained before the fumigation process. Wheat samples from mills (Russian, Ukrainian, and Egyptian) were randomly taken (500 gm each) before milling. French wheat was randomly sampled from silos. Egyptian soft wheat was collected before cleaning, while Egyptian hard wheat was sampled directly before milling. Wheat flour samples (Russian, Ukrainian, Egyptian hard, and Egyptian soft) were obtained from the end of the milling line. Wheat products (Egyptian Baladi flatbread, Pasta (Elbows), pan bread, and Baguette bread) were randomly selected from the local market in Cairo, Egypt (in May 2023) following ISO 24333 and Egyptian Organization for Standardization and Quality EOS guidelines [20,21].

Analytical methods:

Chemical analysis:

Moisture, protein, fat, and ash content were determined using the methods specified by the Association of Official Analytical Chemists (AOAC) and EOS [22,23]. Total carbohydrates were calculated by the difference using the equation: Total Carbohydrate (%) = 100 - (protein% + fat% + ash%).

To ensure accuracy and precision, three replicates were conducted as part of the research plan to verify the obtained results and measure relative differences.

Heavy metals and Minerals:

Metal ion concentrations of lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), potassium (K), magnesium (Mg), and copper (Cu) in wheat, wheat flour, and selected products were analyzed using the Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) Model Agilent 5100

Synchronous Vertical Dual View (SVDV) Serial No. MY15180008, following APHA [24] guidelines. Accuracy and precision were verified using external reference and standard reference materials, with quality control samples from the National Institute of Standards and Technology (NIST) used to verify instrument readings. At spectroscopy lab, central laboratories network, national research center, Dokki, Giza, Egypt.

The limits of detection (LOD) and limits of quantification (LOQ) for various metals are as follows: Cadmium has an LOD of 0.002 mg/L and an LOQ of 0.0076 mg/L; Lead has an LOD of 0.0077 mg/L and an LOQ of 0.026 mg/L; Mercury has an LOD of 0.002 mg/L and an LOQ of 0.0065 mg/L; while Arsenic has an LOD of 0.001 mg/L and an LOQ of 0.0035 mg/L. The limits of detection (LOD) and limits of quantification (LOQ) for various metals are outlined as follows: Iron and Manganese both exhibit an LOD of 0.0029 mg/L and an LOQ of 0.0095 mg/L; Copper has an LOD of 0.025 mg/L and an LOQ of 0.084 mg/L; Zinc displays an LOD of 0.0029 mg/L and an LOQ of 0.0096 mg/L. Additionally, Sodium, Magnesium, and Potassium each have an LOD and LOQ of 2.0 mg/L and 5.0 mg/L, respectively. These values represent the minimum concentrations at which these metals can be reliably detected and quantified within a given sample.

Phosphine residuals determination:

Phosphine residuals were measured by High-performance liquid chromatography-mass spectrometry (HPLC-MS) (Sciex Model) according to El-Shahawi [25]. At the central laboratory for analyzing pesticide residues and heavy metals in foods, Dokki, Giza, Egypt.

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range 50%. The limit of quantification (LOQ) of Phosphine is 0.03 mg/kg.

Ergot determination:

Ergot presence was determined according to Egyptian Standard Specification [26] guidelines.

Statistical analysis:

The collected data were statistically analyzed using the Statistical Package for Social Science (SPSS) software (version 20.0, produced by IBM Software, Inc., Chicago, USA). A completely randomized design, as described by Gomez and Gomez [27], was used. The LSD (Least Squares Difference) test was employed to compare significant differences between treatment means, following Waller and Duncan [28] methodology.

The obtain results are expressed as mean of three replicates data in all experiments

Results and Discussion:

1- Chemical composition of wheat grains.

Chemical composition of tested wheat grains was determined, and the obtained data were shown in Table (1). The provided (table 1) illustrates the diverse chemical compositions of different wheat varieties, encompassing moisture, protein, ash, fat, and total carbohydrate content, comparing them against standard limits according to EOS [26].

Ukrainian wheat slightly exceeded the standard moisture content at 13.5%, while Russian wheat and French wheat approached or surpass the moisture limit. Russian wheat stands out with higher protein (14.2%) and ash (1.8%) content, while French wheat demonstrates a higher moisture level (14%) and lower protein content (10.6%). Egyptian wheat, with lower moisture (10.9%), meet the protein (12.6%) and ash (1.9%) standards. Remarkably, Egyptian hard wheat exhibited notably lower moisture (8.6%), higher protein (14.3%), and lower ash (1.08%) content, along with a higher total carbohydrate percentage (83.42%). The higher moisture content in French and Russian wheat aligns with studied were showed winter wheat varieties from cool, wet climates exhibit higher moisture at harvest [29]. The higher protein content of Russian and Egyptian hard wheat conforms to research on high protein levels in hard wheat varieties grown in dry conditions [30]. The lower ash content of Egyptian hard wheat contradicts findings that ash tends to correlate positively with protein content [31].

Table (1). Chemical composition of tasted wheat grains (g/100g on dry weight basis)

Wheat type	Chemical components (%) **				
	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Total Carbohydrate (%)
EOS**	**≤13**	**≥7**	**≤2**	from1.2 to 2	**>70**
Russian wheat	13.2^{b}	14.2^{a}	1.8^{ab}	2^{a}	82^{d}
Ukraine wheat	13.5^{ab}	13.2^{b}	1.6^{c}	1.7^{b}	83.5^{b}
Egyptian wheat	10.9^{c}	12.6^{c}	1.9^{a}	1.9^{a}	83.6^{b}
French wheat	14^{a}	10.6^{d}	1.7^{b}	1.5^{c}	86.2^{a}
Egyptian hard wheat	8.6^{d}	14.3^{a}	1.08^{d}	1.2^{d}	83.42^{c}
LSD*	0.5	1.2	0.15	0.3	1.5

Means followed by a small letter in common in the same column are not significantly different at 0.05 level of probability. * LSD: Least Significant Difference (at $p \leq 0.05$). The obtained results are represented the mean of triplicate determination. ** EOS = Egyptian Organization for Standardization and Quality.

2- Chemical composition of wheat flour:

The chemical composition of various wheat flours was analyzed and compared to established standard limits (Table 2) according to EOS [26] And EOS [23] Ukrainian wheat flour (72% extraction) had higher moisture (14.5%), slightly exceeded the standard limit of 14%, while shown acceptable protein (12.8%) and ash (1.3%) content. Conversely, Russian and Egyptian wheat flours (82% extraction) demonstrate elevated protein content (13.1% and 10.4%, respectively). Notably, Egyptian hard wheat flour, with a lower moisture content at 13.7% and higher protein content at 14.6%, complies well with the standard limits and a desirable chemical composition.

The lower extraction Ukrainian flour (72% extraction) exceeded moisture standards conforming to [32] study demonstrated higher moisture content in straight-grade flours compared to whole wheat. Meanwhile, the higher extracted Russian and Egyptian flours (82% extraction) produced elevated protein contents agreeing with [33]

Table (2). Chemical composition of wheat flour (g/100g on dry weight basis)
The obtained results are represented the mean of triplicate determination * LSD: Least Significant Difference (at p ≤ 0.05). ** EOS = Eg Organization for Standardization and Quality

	Chemical components (%)				
	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Total Carbohydrate (%)
EOS**	≤14	≥7	≤2	from1.2 to 2	>70
Russian wheat flour 82% extraction	14.10[ab]	13.10[b]	0.92[d]	1.20[a]	84.78[b]
Egyptian wheat flour 82% extraction	14.30[a]	10.40[d]	1.02[b]	1.10[b]	87.48[a]
Ukraine wheat flour 72% extraction	14.50[a]	12.80[c]	1.30[a]	1.40[a]	84.50[c]
Egyptian hard wheat	13.70[b]	14.60[a]	0.94[c]	1.00[c]	83.46[d]
LSD	0.5	1.0	0.15	0.2	1.5

3- Mineral contents in wheat grains.

The mineral contents of wheat grains were analyzed, and the results were presented in Table 3. Egyptian hard wheat exhibited notably higher iron content compared to the other varieties, registered 210 mg/kg, suggested its potential for addressed iron-deficiency concerns [34]. Notably, manganese levels were most prominent in Ukrainian wheat, stranded at 38 mg/kg, which played a pivotal role in metabolic reactions and antioxidant defense [35]. While zinc levels were relatively consistent across varieties, Ukrainian wheat showed comparably higher zinc content at 29.3 mg/kg, crucial for immune function and DNA synthesis [36].

In terms of sodium and potassium, Egyptian hard wheat stood out with higher sodium and potassium levels (150 and 3250 mg/kg respectively), while potassium content was consistent across the different varieties, essential for maintaining fluid balance and nerve function [37]. Magnesium levels were most pronounced in French wheat at 1290 mg/kg, reflecting its significance in various biological processes [38]. Copper content was relatively higher in Russian, Ukrainian wheat, and Egyptian hard wheat (3.25, 3.01, and 4.75 mg/kg respectively), highlighting its role in enzymatic reactions and iron metabolism [39].

The zinc content aligned with reported values [40]. Wheat magnesium averaged consistent with literature stipulating predominant magnesium levels [41]. Adequate wheat copper content was noted [42].

4- Mineral contents in wheat flour.

The comparative analysis of mineral contents in different wheat flour types, detailed in Table 4, revealed substantial discrepancies from established normal limits. Russian wheat flour demonstrated lower iron, manganese, zinc, and potassium content than the recommended thresholds (Fe: 39.5, Mn: 19, Zn: 16.25, and K: 700 mg/kg, respectively). On the other hand, Ukrainian wheat flour displayed levels below the recommended limit for most elements except sodium, while both Russian and Egyptian wheat flours surpassed these bounds [36].

From the results in Table 4, it may be concluded that showed the high sodium levels in Russian and Ukrainian wheat flours, along with exceeding copper content in Egyptian wheat and Egyptian hard wheat flours (Cu: 4.25 and 3.25 mg/kg, respectively).

These nutrients preferentially concentrated in the bran and germ fractions, which were reduced in white flour.
However, zinc was low in Ukrainian flour despite typical zinc accumulation in the endosperm [40], indicated possible low intrinsic grain zinc. Sodium content spanned a high range in Russian and Ukrainian flours, reflecting starchy milling additions like salting agents [43].

Table (3). Mineral contents (mg/kg) of different wheat grains (on dry weight basis)

Samples	Minerals content (mg/kg)						
	Fe*	Mn*	Zn*	Na*	K*	Mg*	Cu*
Normal limit	50	30.9	30	30	3630	1260	2.5
Russian wheat	123	35	27	75	2500	675	3.25
Ukraine wheat	50	38	29.3	123	2825	725	3.01
Egyptian wheat	57.25	9	11	102.5	2475	600	1.75
French wheat	113.5	23	13.5	126	2950	1290	2.5
Egyptian hard wheat	210	27.5	19.5	150	3250	1230	4.75

Fe*= Iron, Mn*= Manganese, Zn*= Zinc, Na*=Sodium, K*= Potassium, Mg*= Magnesium and Cu*= Copper

Table (4). Mineral contents (mg/kg) of wheat flour (on dry weight basis).

wheat Flour samples	Mineral contents (mg/kg)						
	Fe	Mn	Zn	Na	K	Mg	Cu
Normal limit	50	30.9	30	30	3630	1260	2.5
Russian wheat Flour (82% extraction)	39.5	19	16.25	135	700	2325	2.25
Egyptian wheat flour (82% extraction)	173	39.3	35	132	3625	1150	4.25
Ukraine wheat flour (72% extraction)	83	8.5	10.3	145	1625	425	2.02
Egyptian hard Wheat flour	137.5	6.5	7.25	121	1650	720	3.25

Fe*= Iron, Mn*= Manganese, Zn*= Zinc, Na*=Sodium, K*= Potassium, Mg*= Magnesium and Cu*= Copper

Table (5). Minerals content in wheat flour products (mg/kg, on dry weight basis)

Samples	Minerals content (mg/kg)						
	Fe	Mn	Zn	Na	K	Mg	Cu
Egyptian Baladi flat bread	37.75	5.5	6.25	110	4250	1594	1.25
Pan bread	201	31.75	31.75	129	3470	1411	6.75
Pasta (Elbows)	71.25	37.25	41.25	113	3990	1533	5.75
Baguette bread	102.75	35.5	29.25	116	3730	1472	4.25

Fe*= Iron, Mn*= Manganese, Zn*= Zinc, Na*=Sodium, K*= Potassium, Mg*= Magnesium and Cu*= Copper

5- Minerals content in some wheat flour products

The elemental composition of various wheat flour products was presented in Table 5, unveils significant disparities in essential nutrient levels among these products. Pan bread emerged as a notable source of iron with a substantially higher content (201 mg/kg) compared to other products. This observation was congruent with findings from [44], emphasizing the importance of bread as a crucial iron source in the Egyptian diet. In contrast, pasta showcased notably elevated levels of manganese (37.25 mg/kg), zinc (41.25 mg/kg), and magnesium (1533 mg/kg), indicating its potential as a rich source of these essential minerals. Notably, while sodium content remained relatively consistent, potassium levels were notably higher in Egyptian baladi flatbread and Pasta (Elbows). Conversely, pan bread demonstrated higher copper content (6.75 mg/kg), a factor significant for individuals requiring specific dietary considerations.
The exceptionally high iron content of pan bread echoed findings by [45], demonstrating Egyptian

baladi bread as having excellent iron bioavailability to counter deficiencies. Furthermore, pasta's elevated systematic enrichments for these elements via pasta fortification programs [46]. Pan bread's comparatively high copper required assessment for potential environmental copper exposure during processing [47].

6- Heavy metals in wheat grains, wheat flour and their products:

Table (6) provided an extensive evaluation of heavy metal concentrations in various wheat grains samples, heat flour, and wheat-based products. The measurements were compared to the maximum permissible limits established by regulatory authorities. These measurements were compared to the highest allowed limits, set by regulatory authorities or standards. This emphasized the safety measures regarding heavy metal contamination in these food items.

According to Egyptian Standard Specification (ES: 1601-1/ 2010) [26], the prescribed standard limits for heavy metals in these food items were as follows: 0.2 mg/kg for Pb (lead), 0.2 mg/kg for Cd (cadmium), 0.05 mg/kg for Hg (mercury), and 0.1 mg/kg for As (arsenic).

The results distinctly portray that all samples i.e. Russian wheat, Ukraine wheat, Egyptian wheat, French wheat, Egyptian hard wheat, Russian wheat flour (82% extraction), Egyptian wheat flour (82% extraction), Ukraine wheat flour (72% extraction), Egyptian hard wheat flour, Egyptian baladi flatbread, pan bread, Pasta (Elbows), and baguette bread - exhibited heavy metal concentrations substantially below the established maximum limits. All samples had heavy metal concentrations of "< 0.05 mg/kg," indicating that these specific heavy metals were not detected at levels surpassed the limit of quantification.

This would generally agree with research showed heavy metal contamination in wheat tends to be very low when crops were sourced from unpolluted areas [48]. The uniformly low detected metals across the wheat origins and products indicated consistency with

iterature demonstrating minimal wheat heavy metal concentrations when good agricultural practices were followed [49].

7- Phosphine residuals in wheat grains, wheat flour and some of their products:

The results obtained in this analysis provide valuable insights into the safety of various wheat and wheat-based products with regard to phosphine residuals. The phosphine residues of wheat samples and wheat-based products were shown in Table (7). To ensure the safety of these food items, regulatory bodies have established a standard limit for phosphine residuals in wheat and wheat flour at 0.1 mg/kg EOS [26]. Remarkably, all tested samples, which encompassed a diverse range of wheat varieties and wheat-based products such as Russian wheat, Ukrainian wheat, Egyptian wheat, French wheat, Egyptian hard wheat, Russian wheat flour (82% extraction), Egyptian wheat flour (82% extraction), Ukrainian wheat flour (72% extraction), Egyptian hard wheat, Egyptian Baladi flatbread, pan bread, Pasta (Elbows), and baguette bread, showed levels of phosphine residuals "Not detected". These findings provided unequivocal evidence that the phosphine residual levels in these food items were effectively below the detection limit, demonstrating full compliance with the established safety standards.

The absence of detectable phosphine residuals in these food samples was a testament to the effectiveness of proper fumigation practices, which are essential for pest control during grain storage [50]. The complete lack of detectable phosphine residuals agreed with research demonstrating that when good storage practices and label requirements for phosphine fumigation were followed, residues were typically non-detectable [51].

manganese, zinc, and magnesium concurred with

8-Ergot in wheat Grain:

In the conducted study, the mycotoxin analysis of wheat grain samples, results were presented in Table (7). According to EOS [26], the standard limit for ergot in wheat was 0.05%. It was found that all tested samples, including Russian wheat, Ukrainian wheat, Egyptian wheat, French wheat, and Egyptian hard wheat, met the regulatory limits for Ergot. Mycotoxins, particularly ergot, were identified as toxic compounds produced by fungi, capable of contaminating grains under certain conditions. However, the absence of mycotoxins in the tested samples indicated the implementation of effective quality control measures during cultivation, harvesting, and processing stages [52].

Health Risk Assessment:

The risk assessment of potential contaminants in wheat grains, wheat flour, and wheat-based products revealed a high level of safety and compliance with established regulatory standards. The concentrations of heavy metals, including lead, cadmium, mercury, and arsenic, were consistently below the maximum permissible limits across all samples analyzed. Furthermore, the absence of detectable phosphine residuals and ergot (mycotoxin) contamination demonstrated effective fumigation practices and adherence to quality control measures during cultivation, storage, and processing. These findings indicate a minimal health risk associated with the consumption of these wheat and wheat products, provided that good manufacturing practices are maintained throughout the supply chain. The overall results provide assurance to consumers regarding the safety and suitability of these essential food items for human consumption.

Table (6). Heavy metals in wheat, wheat flour and some of their products (mg/kg, on dry weight basis).

Samples	Heavy metals (mg/kg)			
	Pb*	Cd*	Hg*	As*
Standard limit (Maximum)	0.2	0.2	0.05	0.1
Russian wheat	< 0.05	< 0.05	< 0.05	< 0.05
Ukraine wheat	< 0.05	< 0.05	< 0.05	< 0.05
Egyptian wheat	< 0.05	0.09	< 0.05	0.06
French wheat	< 0.05	< 0.05	< 0.05	< 0.05
Egyptian hard wheat	< 0.05	0.08	< 0.05	0.07
Russian wheat flour (82% extraction)	< 0.05	< 0.05	< 0.05	< 0.05
Egyptian wheat flour (82% extraction)	< 0.05	< 0.05	< 0.05	< 0.05
Ukraine wheat flour (72% extraction)	< 0.05	< 0.05	< 0.05	< 0.05
Egyptian hard wheat flour	< 0.05	< 0.05	< 0.05	< 0.05
Egyptian Baladi flat bread	< 0.05	< 0.05	< 0.05	< 0.05
Pan bread	< 0.05	< 0.05	< 0.05	< 0.05
Pasta (Elbows)	< 0.05	< 0.05	< 0.05	< 0.05
Baguette bread	< 0.05	< 0.05	< 0.05	< 0.05

* Pb = lead, Cd = Cadmium, Hg= Mercury and As= Arsenic

Conclusion:

In conclusion, the study on wheat and wheat-based products in the Egyptian markets demonstrated that the samples consistently meet high-quality standards. Their chemical composition showcases a harmonious balance of moisture, protein, and ash, ensuring optimal nutritional value. The diverse protein content among the samples offered exciting possibilities for a varied and nutritious diet. Furthermore, the analysis revealed that certain samples exhibited elevated levels of essential nutrients, providing an added health benefit. Notably, all samples demonstrated exceptional safety standards, as they were free from heavy metal contamination, including lead, cadmium, mercury, and arsenic, which remained well below the permitted limits. Additionally, the absence of phosphine residuals in grain, wheat flour, and products, as well as the complete absence of Ergot contamination in all tested wheat samples, underscored the strict adherence to safety regulations.

Recommendations:

To ensure the safety and quality of wheat and wheat-based products in Egypt, it is recommended to enhance food safety regulations, raise consumer awareness, and invest in research and innovation. Collaborative efforts among relevant stakeholders, adoption of sustainable practices, and continuous monitoring are crucial for safeguarding public health and preserving the integrity of these essential dietary staples.

Conflicts of interest

The authors declared that present study was performed in absence of any conflict of interest.

Table (7): The Phosphine Residual and Ergot (Mycotoxin) of wheat, wheat flour, wheat products (on dry weight basis).

Samples	Phosphine Residual (mg/kg)	Ergot (Mycotoxin) (%)
Standard limit (Maximum)	0.1	0.05
Russian wheat	ND	ND
Ukraine wheat	ND	ND
Egyptian wheat	ND	ND
French wheat	ND	ND
Egyptian hard wheat	ND	ND
Russian wheat flour (82% extraction)	ND	---
Egyptian wheat flour (82% extraction)	ND	---
Ukraine wheat flour (72% extraction)	ND	---
Egyptian hard wheat flour	ND	---
Egyptian Baladi flat bread	ND	---
Pan bread	ND	---
Pasta (Elbows)	ND	---
Baguette bread	ND	---

*ND: Not detected **--- Not determined

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