Nutritional value and quality aspects of wheat produced and consumed in Albania

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Abstract. Wheat and its flour-processed foods constitute the staple food of the Albanians. Nutritional importance relates to its role as an essential source of microelements and its flexibility to be processed in a wide range (e.g., bread, pasta, pastry, baked products). Global wheat markets have become increasingly demanding concerning wheat quality indicators. The country has a tradition of wheat cultivation connected with politics in the past decades. The study has analyzed the wheat quality according to physicochemical indicators: protein, gluten, starch, moisture, and sedimentation index, by Near-infrared spectroscopy (NIRS). A non-destructive technique based on electromagnetic wave interactions of molecules in the analyzed matrix. Seventy-five wheat samples were collected from agricultural regions during the harvesting season 2022. Protein content varied in the interval 9.6-15.0 %, with an average of 12.7 %. The gluten content analyzed was 19.4-37.5%, with an average of 27.5%. Starch content varied in the interval 66.3 -71.5 %, with an average of 68.9%. The sedimentation index was measured in the interval 21.1-57.8 with an average value of 37.6. Finally, the moisture level varied at 9.8-12.5%, indicating no wheat sample exceeded the threshold max level of 14.5%, in accordance with national and EU food legislation.

1 Introduction

Cereals constitute the main seed group in the human diet. Wheat grain belongs to the genus Triticum, part of the *Poaceae* family, which includes other cereals like corn, barley, rice, and rye. They are cultivated for the edible grain seeds when ground, and consumed by people [1]. There are two wheat species: soft (common) wheat, *Triticum aestivum*, and durum wheat, *T. durum,* in modern times. Wheat (*T. aestivum*) and its flour-processed products are essential to people's diets. It grows globally, except in tropical regions [2].

The growing world population has increased pressure on the global cereal markets, demanding quality control throughout the cereal commodities supply chain. The big three cereal grains (rice, wheat, and maize) play roles as staple foods as primary daily sources of carbohydrate-based energy. Even though there are differences in preferences for cereals among geographical regions, the wheat commodity is essential to Europeans and the global population [2, 3].

The grain comprises bran, endosperm, and germ, each with a different chemical composition. Wheat consists of primary metabolites: carbohydrates, proteins, and in less amount by fats. The bran is rich in fibers; the endosperm contains substantial proteins, carbohydrates, and iron; the germ contains vitamins and trace minerals, unsaturated and polyunsaturated fats [4, 5].

Gluten proteins make wheat a unique cereal in its suitability for bread production and a dozen other dought uses. The main component of wheat flour is starch, followed by protein, which is the gluten-forming gliadins and glutenin. The fat content is low. Wheat is a significant source of energy, fiber, vitamins, and minerals in our diet. Wheat is unique among the food grains. It contains storage proteins that form a cohesive dough with extensibility and elasticity to allow the growth of gas bubbles (air and carbon dioxide) and the retention of the bubble structure throughout the bread-baking process [2, 4].

On average, world wheat production in 2021 reached about 900 million tons, cultivated on some 244 million hectares, with a world average yield of 3.71 tons/ha [6]. In the European Union, more than half of the cereal area planted is wheat. Maize and wheat are the main grains planted in Albania. Their cultivation is throughout the country, mainly in Fieri, Elbasan, Korça, and Tirana districts. Country grain production for 2021 indicates that maize and wheat are the two main cereals produced in the country, with wheat reaching 225 thousand tons.

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Table 1. Cereal production in Albania during the harvesting year 2021, in tons [7].

No.	Prefecture	Cereals	Wheat	Maize	Barley	Oats
1	Berati	32953	11636	17190	223	3904
2	Dibra	47266	7588	38516	302	227
3	Durrësi	41333	10404	29101	36	1792
4	Elbasani	98249	35297	57142	198	5341
5	Fieri	168386	62886	88517	4939	12044
6	Gjirokastër	16979	6327	8130	-	2522
7	Korça	85094	45950	26783	7983	2762
8	Kukësi	14586	2010	11271	-	547
9	Lezha	33138	11131	22007	-	-
10	Shkodër	52793	5105	47688	-	-
11	Tirana	46434	17558	25943	1409	1508
12	Vlora	54144	9280	41982	220	2662
	Total	**691353**	**225171**	**414271**	**15310**	**33309**

The wheat flour quality and safety are of public concern since it is related to the flour products' quality and human health [8]. Application of Near-Infrared Spectroscopy (NIRS) in grain commodities analyzes many quality and quantity parameters [9]. Moisture and protein content are the most widely used and have achieved worldwide adoption due to their economic importance. The accuracy of the respective NIR model's approach. Other NIR applications involve macroconstituent analysis (starch, oil), essential constituents (amino acids, beta-glucans, dietary fibers, amylose), quality control during processing (hardness, dough development, wet milling), grading and classification (color class, vitreousness, insect), food quality (mycotoxins, contaminants, ergot bodies) [10, 11]. The NIRS technique is advantageous due to its numerous advantages. It reduces the test time and costs. It does not require chemicals and sample preparation, making it superior to traditional chemical analytical methods, especially in industrial quality control and process monitoring applications [9].

American Society for Testing and Materials (ASTM) has defined near-infrared light as part of the electromagnetic spectrum in the range of 780–2500 nm, between the visible and mid-infrared light spectrum [12]. NIR spectroscopy is a technique that applies the NIR portion of the electromagnetic spectrum and can provide complex structural information related to the vibration behavior of chemical bonds. NIR spectra present the overtones and combination of hydrogen-containing C–H, O–H, and N–H groups, which are the primary structural components of organic compounds, such as water, lipids, and proteins [9, 11, 12].

The measurement process consists of the following steps: (1) spectral data acquisition; (2) data pre-processing to eliminate noises; (3) building calibration models obtained by suitable reference methods; and (4) model validation using another set of samples without the calibration set [13]. Among two pillars - fundamentals and instruments- a third is crucial in NIR spectroscopy - data analysis. Data analysis uses machine learning to map the NIR absorption or transmittance values to the desired sample properties.

The NIR spectroscopy algorithms used to "interpret" optical data for absorbing samples may be explained as different approaches to relating sample absorbance (A) at specific wavelengths to analyte concentrations via Beer's law.

So, the multi-regression equation commonly used for calibration is:

$$Y = Bo + Bi(-\log Ri)N + E \quad (1)$$

Where:

Y = percent concentration of the absorber
Bo = intercept from regression
Bi = regression coefficient
i = index of the wavelength used and its corresponding reflectance (Ri)
N = total number of wavelengths used in regression
E = random error

2 Material and method

2.1 Wheat samples

A total of 75 wheat samples from the central producing regions, Fieri, Elbasan, and Korça, were collected during the summer of 2022, directly after harvesting. The wheat samples were prepared according to the sampling procedure and placed in bags. Finally, they were transferred to laboratory premises and kept at 4°C in a dark place until analysis.

2.2. Chemical analysis methodology

The routine determination of grain protein content generally involves near-infrared (NIR) spectroscopy, applied to whole grain, milled grain, or flour, based on correlations to total nitrogen analyses. The laboratory analyses were conducted on representative samples of the total material of about 75 samples and used for calibrating a PLSR model to predict water, protein, starch, β-glucan, fat, and % moisture.

Fig. 1. FOSS infrared apparatus for analyzing the physico-chemical parameters of cereals.

Infratec ™ 1241 is a device that analyzes whole grains using near-infrared technology to test multiple parameters—Standard EN 15948:2015 - Cereals - Determination of moisture and protein - Method using Near-Infrared-Spectroscopy in whole kernels. The parameters analyzed are moisture, protein, gluten, sediment, starch, and fat. It consists of a Hopper where a sample of at least 400g is placed. Transmission mode measurements are made at a lower wavelength of 570 - 1050 nm, while primary information for reflectance measurements is obtained between 1100 - 2500 nm. The higher level of light energy in the lower range allows deeper penetration into the interior of the grain and not only the surface but also the interior of the seed kernel.

3 Results and discussion

Near-infrared (NIR) spectral patterns from seeds carry surprisingly consistent information on functional food quality that seems almost unreasonable [14]. NIRS is a non-destructive and rapid technique that is increasingly used for food quality evaluation in recent years. It provides us with more information to research the quality of food products [13]. One of the oldest and most important applications of NIRS in the food and agriculture sector is for measuring protein content in grains, especially wheat. In recent years, spectral analysis technology has been used for testing seed quality, such as determining protein, wet gluten, moisture, ash, and sedimentation in wheat flour. The NIRS technique for wheat quality control can be applied in two diverse ways: as an analytical method for accurate and rapid determination of composition in trade and as a screening method in wheat breeding and processing [11, 15]. Each NIRS instrument is designed to contain a sample compartment, light source, wavelength selection system, and detector. Measuring wheat protein content has succeeded due to strong and broad absorption by the N–H bonds in the NIR spectral region. The importance of accuracy is so high because premiums of 1.30–1.50$ are paid for increments of 0.1 % in protein content per ton [16]. In reflectance, whole grain samples were scanned in a NIR monochromator instrument (400-2500 nm). Partial least squares (PLS) were used to develop calibration equations for the quality characteristics of whole wheat [17].

As one of the various technologies for evaluating food quality, the NIRS technique has its advantage in food analysis. The spectral measurement for one sample may finish in 1 minute. This method is less expensive than traditional methods because of the lack of solvent and expensive instruments [13].

Accordingly, the primary goals of this research are as follows: (1) determine protein, starch, and moisture content in wheat flour using traditional chemical methods and obtain NIR-HSI image information [18].

NIRS was particularly useful due to the numerous advantages it provides. The application of the NIRS technique significantly reduces the test time and costs. It does not require chemicals and sample preparation, making it superior to traditional chemical analytical methods, especially in industrial quality control and process monitoring applications. In the case of the cereal-based food and feed industry, benchtop NIRS systems with calibrations based on single-cereal species are routinely utilized [9].

The prerequisite for using the NIRS method is an appropriate calibration model developed to relate the compound (or property) of interest to the sample's spectral data. NIRS calibration model development is very demanding due to the complex composition of analyzed samples, resulting in severe overlapping of interfering bands representing the component (s) (or properties) of interest. NIRS devices, chemometrics techniques, and computer technology have contributed to developing the NIRS technique currently used for testing a wide range of foodstuffs [15].

Gluten composition in wheat flour is an important quality parameter because it strongly correlates to baking quality. Protein quantity is often insufficient to predict baking quality because different baking quality was observed for flours with comparable protein content but different gluten compositions [12].

The quality and quantity (normal variation ranges 8–16%) of wheat flour protein affects the dough properties and, consecutively, the quality of the final product. The main components of wheat flour are protein (about 10–12%) and starch (about 70–75%), while the secondary components are polysaccharides (about 2–3%) and lipids (about 2%) [19]. The proteins form a three-dimensional structure during dough mixing, giving elasticity, helping it rise and keep its shape, and providing strength and a chewy texture to the baked goods.

Table 2. Chemico-physical parameters measured in the wheat commodity produced during 2022 (%).

Parameter	Min	Max	Mean
Proteins	9.20	15.10	12.54±1.27
Humidity	9.50	12.20	10.86±0.53
Starch	66.80	72.00	69.59±1.21
Gluten	18.20	39.20	28.17±4.34
Sedimentation index	19.20	59.00	39.35±8.62

The protein content of some common cereals varies, e.g., Barley (9-12% weight of whole grain), maize (8-12%), Oats (12-15%), Rye (12-15%), Wheat (9-16%). Its protein content (12-16%) is higher than soft wheat to specify durum wheat [3, 19].

Protein content is determined using different methods.

Table 3. Methods applied to determine the protein content of cereal grain wheat [19].

Process	Material assayed	Method
Mill	Grain Flour	NIR NIR
Extract	Protein in solution	Biuret
Hydrolyze	Amino acids	Liquid chromatography
Alkaline digestion	Amide N	Titrate ammonia released
Acid digestion	Ammonia or nitrogen	Kjeldahl method

This study's objective was to apply NIR spectroscopy for the cereal quality analysis of physicochemical parameters, protein, gluten, starch, sedimentation index, and moisture in wheat grain produced in Albania. Seventy-five wheat samples were collected during the harvesting season in 2022. Protein content varied in the interval 9.2-15.1%, with an average of 12.5%; of them, only four samples were below the threshold (10.5%) [16].

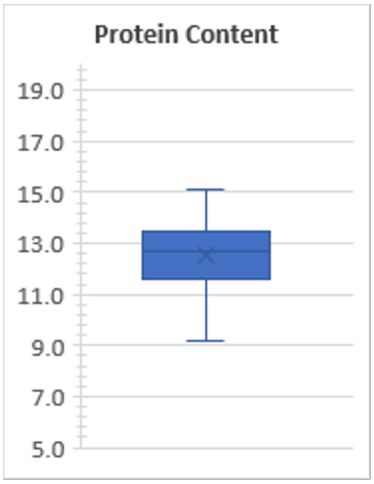

Fig. 2. Protein content in wheat samples (%).

Starch is the most widespread macromolecule in the plants' kingdom, composed of chains of α-1,4 linked glucose in helices, bridged by α-1,6 bonds. It occurs as granules in the grain endosperm. Amylose, mainly linear chains of α-(1–4)-linked glucose, and amylopectin, usually the major component, being highly branched polymers, are the two major compounds of starch [2]. NIR analysis of the starch in the analyzed wheat presented an interval of 66.8 -72.0%, with an average of 69.6%.

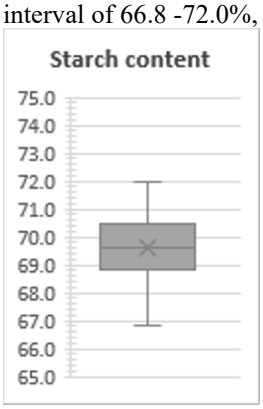

Fig. 3. Starch content in wheat samples (%).

Worldwide, plant proteins contribute more than half of our dietary supply of protein. This protein harvest includes wheat, rice, and maize from the three major cereal grains [19]. The gluten content varied in the interval 18.2-39.2%, with an average of 28.2%. The minimum gluten content of wheat flour should be about 24 % (wet) [20]. Only four samples, or 5.3% of analyzed wheat samples, were found under 24%, showing the very good quality of the wheat produced during 2022.

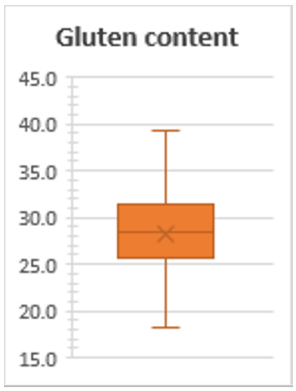

Fig. 4. Gluten content in wheat samples (%).

The sedimentation index interval is 19.2-59.0%, with an average value of 39.35%. The sedimentation test is a physicochemical test that helps provide information on wheat flour's baking quality. The sedimentation value, according to Zeleny (Zeleny value), describes the degree of sedimentation of flour suspended in a lactic acid solution, referring to a standard time interval. This is taken as a measure of the quality of baking. A higher gluten content and a better gluten quality give rise to slower sedimentation and higher Zeleny test values [21].

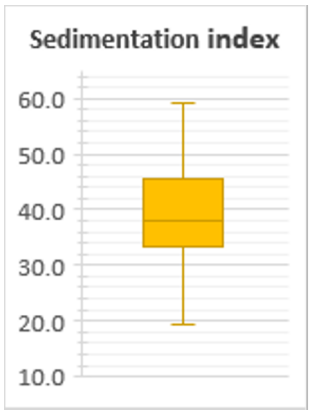

Fig. 5. Sedimentation index.

The moisture content is critical for the storage of flour. High moisture content in flour promotes infestation with mold and worms during storage. According to EU regulation, the moisture varied at 9.5-12.2%, with no wheat sample exceeding the threshold max level of 14.5%. The Average protein content values were 12.54±1.27%, with maximum values of 15.1%. One of the critical concerns regarding food safety worldwide is the mycotoxin contamination of cereals. Regulated and non-regulated mycotoxin contamination is a continuous threat to the world population due to the importance that cereals like wheat and maize are stapled foods. Chronic exposure may lead to several toxic adverse effects on target organs. Issues on mycotoxin contamination have been in focus in Albania regarding cereals contamination [22, 23]. Using cereals and their by-products as feed may result in animal health threats and human exposure to dairy products [24]. Still, other constituents, such as aflatoxin in corn or deoxynivalenol in wheat, have received the attention of NIR practitioners despite the concentrations of their natural occurrence in bulk lots, at sub-ppm levels, being

below the detection limits of NIR reflection or transmission spectroscopy [25, 26].

Application of the NIR technique in grains for control the quality indicators is a fast method, enabling to the decision-makers a good acting tool for preserving the quality of the grain and their related products in the storage and production lines.

4 Conclusion

The objective of this study was NIRS application for analysis of quality parameters: protein, gluten, starch, and sedimentation index to whole kernel wheat produced in Albania. Quality control of wheat and wheat flour is economically important for consumer protection. NIR spectroscopy application for cereal quality analysis indicates that wheat commodity production in Albania is of high quality. Climate change impacts both food security and food safety of cereal production. Implementing low-cost and portable techniques such as NIRS will support farmers in cereal production and increase awareness of the importance of quality parameters in the economic aspect.

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