OVERVIEW OF METHODS AND TOOLS USED TO DETERMINE THE QUALITY OF WHEAT STORED UNDER VARIOUS CONDITIONS

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Keywords: wheat, materials, equipment, modern, quality.

ABSTRACT

The requirement of new efficient, rapid and reliable techniques for assessing the content and quality of wheat proteins has led to changes in the available methods as well as the development of new methods. The empirical processes used to determine wheat quality are the basis for the development of new methods and equipment designed to facilitate and improve the way in which the characteristics of cereals stored in the long term are determined. Many factors influence the quality of wheat, including: storage mode, methods to combat infestation, the influence of environmental factors, all of which lead to the degradation of the grain over time. The objective of this work was to assess the newest methods and equipment used to specify the quality of stored cereals.

INTRODUCTION

Wheat is part of the basic diet of most people, but also of animals around the world. Wheat is grown in a large number of countries, but also in areas with a very different climate where cereal production can be small but also on a large scale. Depending on the climate in which wheat is grown, environmental factors may affect it before and after harvesting, this may lead to a degree of exposure to any problems that may arise by the time of delivery of the stored cereals to users (Fleurt-Lessard, 2002; anonymous, 2014). It is one of the largest grain crops grown in the world (Walia, 2015), with an estimated yield of 740 and 751 million tons for the 2016 and 2017 harvest years (USDA, 2016). The quality of wheat can be defined by the qualities related to physical condition, physiological performance and genetic traits. Compared to possible losses due to delayed harvesting, cereals are prone to quality losses during storage, especially when stored improperly. The main factor that can influence wheat quality during storage is air ventilation, as it directly influences the respiratory rate of cereals. Hermetic grain storage can ensure grain preservation for a longer period compared to traditional storage (Jonfia Essien et al., 2010) (Tubbset al., 2016). The preservation of cereals that are of superior quality today is a real concern around the globe. Crop quality deterioration can start right in the field before harvesting, and worsen in poor storage areas over time (Kent and Evers, 1993). High quality wheat is the most nutritious, free of pathogens, physical and chemical contaminants (Weinberg and colab., 2008). Research is currently being carried out to improve but also to panning new methods to overcome the shortcomings in current methods and equipment for determining grain quality. In recent years, many different analytical processes have been used to determine the quality parameters of wheat. On farms, manual samples, traps and probes have been used to determine the presence of insects. Manual inspection, screening, and Berlese funnels are currently used to detect insects in grain handling facilities. These means are not effective and are time-consuming. Acoustic identification, carbon dioxide measurement, uric acid measurement, infrared spectroscopy and soft X-ray method have the potential for industrial scale use for detecting insects in grain samples., 2000; Karunakarana and colab., 2004; Koljonen and colab., 2008; Neerthirajan and colab., 2005.

HECTOLITRE MASS

For some samples the hectolitre mass (kg/hl), the protein content (12 % protein base), the mixing time of the dough (min) and the volume of the bread (12 % protein base) was determined in a quality control laboratory. The hectolitre mass was determined using a two-level funnel according to the American Association of Cereal Chemists (AACC) method 55-10, 2000. The resulting weight was divided by 5 and expressed in kg/hl. The protein content was achieved by the AACC method 39-11.01, using a FOSS Grain Analyzer 1241, with NIR technology. Mixographic analysis (AACC 54-40 A method) was carried out to determine the growing time of the dough (mixing time) of each sample (American Association of Cereal Chemists (AACC), 2000).

DETERMINATION OF HUMIDITY

Samples were weighed and placed in screw glass containers. A small amount of distiled water was added slowly with frequent agitation until the moisture levels of the total mixture reached 15 and 25%. Hydrated samples were stored for 1 hour at 120 °C in a convection oven (P-select, Barcelona, Spain). After cooling to room temperature, the samples were placed on a 100-mesh sieve for further analysis. The moisture content was measured before and after determination of thermal humidity using a humidity analyzer (DBS60-3, Kern, Balingen, Germany) (Impact of heat moisture treatment and hydration level on physico-chemical and viscoelastic properties of doughs from wheat-barley composite fours, 2017).

THE CONTENT OF FOREIGN BODIES

The content of foreing bodies in cereals is difficult to detect using conventional measurement methods. The field of reflection imaging of terahertz time spectroscopy is proposed as a non-destructive and highly penetrating technique for detecting foreign bodies found in wheat samples with different surface depths. Image pre-processing and threshold segment algorithm are used to improve terahertz images. Foreign bodies that are found in wheat samples can be detected and analyzed just as well in flour samples. Results indicate that terahertz reflection imaging technology seems to be a useful tool for detecting the presence of foreign bodies in cereals (Detecting foreign bodies in cereals with terahertz reflection Imaging, 2019).

IMAGING SYSTEMS FOR ASSESSING GRAIN QUALITY

Visualization systems are non-destructive, non-contact and non-invasive methods of assessing the quality of food grain. The approach can provide rapid and accurate information on external quality aspects of cereals. They may be used for the identification and classification of cereal types and varieties, extraneous matter, insect infestation, microbial infection and discoloration of cereals. It is possible to monitor grain quality at different stages of grain processing and to use automated vision systems for grading applications. The biggest challenge is to integrate these systems with those that can explain internal grain quality attributes. In the near future, with growing application demands and research developments, auto vision systems can offer effective solutions for different applications for cereal quality assessment. The discoloration of the cereals may occur under poor storage conditions and that can significantly affect the sales (Jinorose and colab. 2010). In a similar study using discriminatory multivariate analysis, (Ahmad and colab.,1999) developed a classification model based on red, green, blue to identify fungal/viral damage in soybean seeds (based on variations in color characteristics). Black germs that are caused by *Alternaria sp*. have also been identified in wheat using Auto vision CCD systems with acceptable levels of accuracy. The computerized view of an object and the perception of its optical characteristics for the interpretation of results is known as an Automatic vision (JHA, 2010). Digital information of the object is obtained from the acquired image and qualitative/quantitative results are provided using the appropriate image processing algorithm (Gunasekaran 2000; Sun 2011). Image acquisition can be done using cameras (Vizen and colab. 2004; sonka and colab. 2008) or flat bed scanners (Paliwal and colab. 2004; Shahin and Symons 2005).

METHOD FOR DETERMINING AFLATOXIN CONTAMINATION IN WHEAT

For this determination, ground wheat flour was taken from random samples for the quantification of aflatoxins using the VicamAfla HPLC column. HPLC-grade methanol (1,5 ml) was used to develop the affinity column. 1,5 ml of purified water has been added to bring the final volume to 3 ml. The probe was performed prior to injection (Saleemi and colab. 2017). The sample was analyzed on HPLC (20A promotion HPLC System with fluorescent detector, Shimadzu Scientific instruments, Japan). For the quantification of aflatoxin, the peaks obtained were compared with the standard peaks from Sigma chemical Corporation Louis, MO, within a range of 1-50 ppb. The certified reference material of SUPELCO Bellefonte, PA, was used to ensure the analytical quality of the applied method. As a result, no aflatoxins were recorded in any of the evaluated samples (Preserving wheat grain quality and preventing aflatoxin accumulation during storage without pesticides using dry chain technology, 2020).

BIOCHEMICAL TESTING OF STORED SEEDS

Omeg Analyzer (Omeg Analyzer G, Bruins instruments, USA) has been used for the photometric determination of starch and protein content. For the determination of malondialdehyde content, the seed sample (1 g) has been homogenized in a solution of 10 % trichloroacetic acid. Absorption of the supernatant collected after centrifugation of the reaction mixture at 450, 532 and 600 nm was recorded to determine the malondialdehyde content (Zheng and colab., 2006).

THE QUALITY OF WHEAT

A Foss NIR system (model 6500, Foss NIR systems, Silver Spring, MD), which measures wavelength refraction 400-2498 nm, is usually used to check wheat quality. This device was used to determine the protein content of the grain, the calibration of the machine was carried out using the Kjeldhal method, (American Grain Chemists Association, 2000). The grain samples were ground into a Mill 3100 laboratory mill using a standard 0,8 mm sieve (Perten instruments, Hägersten, Sweden). The resulting flour with groats was immediately transferred to an airtight container, from which double samples (10 g flour/sample) were taken to wash the gluten. The wash was performed with a Glutomatic 2200 (Perten instruments) according to AACC 38-12 (AACC, 2000) method, with at least two repetitions per sample. A cyclonic sample mill (UDY Corporation, Fort Collins, CO) (Peña and colab., 1990) was used to determine SDS sedimentation. Wheat samples (3 kg) before being ground were held at 16% moisture, 22 ° C for 24 hours. The grinding was carried out with a Quadrumat SR. (Brabender instruments, Duisburg, Germany). The quality of the flour has been tested using a Chopin alveograph (CHOPIN technologies, Villeneuve-la-Garenne Cedex, France) in accordance with method AACC 5430-a 1194 (AACC, 2000) (Sowing Date and

Wheat Quality as Determined by Gluten Index, 2015).

DETERMINATION OF WET GLUTEN CONTENT

The determination of wet gluten was made from wheat (*Triticum aestivum ssp. Vulgare, Triticum aestivum ssp. Spelta*). The wet gluten was washed from flour with the groats (at 14% moisture) by the Perten glutomatic system with 2% NaCl solution (ICC155, AACC 38-12.02) and with deionized water, using the manual method (AACC 38 10.01). The mechanically washed gluten was analyzed for other parameters – gluten index and uniformly dried gluten content by the same technique (AACC 38-12.02). The protein content of the cereal has been determined by Kjeldahl N * 5.7; ICC 105/2 the volume of Zeleny sedimentation (ICC 116/1, ICC 118) and the Hagberg-Perten drop index (ICC 107/1) have been determined for all samples. The grain samples (moisture content 11,9 ± 1,6%) were ground with Perten Lab Mill 3100. The average mechanical gluten is smaller than the one washed by hand. This difference is largely associated with the characteristics of gluten-water. When gluten is strong, the index values of hand-washed gluten are lower compared to those washed by Glutomatic. On the other hand, when gluten is weak, the index values of hand-washed gluten are higher. Many parameters of wheat quality are strongly correlated, the quality of end-use is an extremely complex phenotype. An example is that different varieties may have the same glutenic index, protein content or both, but a different alveolar index. The gluten index is a determining factor in the assessment of wheat crops, but information on this particular parameter is not sufficient. From the farmer's point of view, the best way to prevent low gluten-acid yields is to choose varieties which inherently produce high gluten-index grains. Another method is Glutopeak equipment, patented in recent years by the Brabender company (Duisburg, Germany), is a fast, high shear method to study gluten properties such as mixing, aggregation, expandability and tenacity in a diluted water-flour suspension (FU et al., 2017; Hadnaev and colab., 2016; LU and Seetharaman, 2014; Tuesday and March, 2015; Melelky and Colab., 2011). The instrument has as its features: The lifting time, corresponding to the moment when gluten aggregation begins; the maximum peak time corresponding to the maximum torque; the maximum torque corresponding to the deformation that occurs due to optimal gluten aggregation; (Karabhuman and colab., 2015; Tuesday and colab., 2015). The advantages of this Glutopeak apparatus, are its high sensitivity, short analysis time and small sample demand, compared to other instruments used for reological analysis (Chandi and Seetharaman, 2012; Melgori and colab., 2018). Due to these advantages, Glutopeak has the prospect of increasing wheat quality, especially in the early generation selection, where time and sample quantity are limiting factors (Guzman and colab. 2016b). Previous studies have shown that the Glutopeak tester can be used to compare all types of flour, including whole wheat flour (Chandi and Seetharaman, 2012) and durum wheat flour (Tuesday and month, 2013). In a recent study, a very significant correlation has been established between Glutopeak MT and the absorption of farinographic water (FU and colab., 2017). The values of Glutopeak MT and PMT have been determined to characterize weak and strong gluten in a good way (Karabicephuman and colab., 2015). It was also found that Glutopeak MT showed a high correlation with the dough strength parameters (Huen and colab., 2018). A recent study has shown that the stability of the pharinograph can be predicted by the GlutoPeak tester using whole wheat flour (Melgori and colab., 2018).

FALLING NUMBER

Falling number is a determination made to see if the effect of wheat sprouting after harvest tends to increase during storage; however, the storage requirements and conditions affecting changes in the falling number index are very little understood. Increases in the falling number index of artificially sprouted cereals during storage were affected by temperature, but for moisture no obvious change was observed remaining in the range of 10,0-13,0% (Storage conditions affecting increase in Falling Number of soft red winter wheat grain, Taehyun Ji and Byung-Kee Baik, 2016). Falling number index shall be carried out in accordance with the standard ICC method 107/1. The method, based on viscosity, was used to make an immediate assessment of the activity of α-amylase of wheat flour.

THE REOLOGICAL PROPERTIES OF THE DOUGH

The reological properties are assessed with the Chopin NG alveograph (Chopin, Villeneuve-la-Garenne, France). The flour quality parameters as specified in the standard (ISO, 27971 International Standard, 2008), dough tenacity (P), dough extensibility (L), deflection energy (W), curve configuration report (P/L) and inflation index (G) are evaluated. The Alveograph was chosen for its ability to offer at the same time several parameters directly associated with the dough properties and because it is the standard method for assessing the technological properties of the flour and dough (Indrani and colab., 2007). The new Mixolab device brought new information on the reological behavior of the dough during the bread making process, since it allows the determination of the mixing and heating properties of the dough in a single test using the ‘Chopin’ protocol option (Kahraman K and colab., 2008, Codina GG and colab., 2012). Myxolab can be used for the reological analysis of flour, but also for other purposes, including: development of gluten-free products (Marco C and colab., 2008). The analysis of the reological qualities of dough in wheat varietal flours in the Balkan region and their bran using the Bra bender (Farinogaph and Amylovaph) and Chopin Mixolab equipment generally showed a positive correlation. The research carried out with the Brabender Amilogaph was in accordance with ICC Standard No 1972 method for using the Brabender Amylgraph, which blended 80 g of flour with 14 % moisture with distiled water, to homogenize the mixture with a glass spatula and place it in the amograph flask with an initial temperature of 250 ºC, raise the temperature to the maximum viscosity at 1,5 ºC/min. The pharynograph shows results on how the dough behaves during mixing, this method is based on the determination of the dough attributes on the basis of water absorption qualities and its behavior during the constant mixing period. The flour was evaluated for the reological properties by passing through Brabender Farinogaph (ICC-Standard 115/1, 1992, AACC method No. 54-21, 1995), (Anon, 2000) following the procedure of constant weighing of the flour. The behavior and the resistance to mixing were recorded on a graph and the graphs were interpreted for the physical characteristics of the dough, such as the dough development time, the dough stability, the mixing tolerance index and the softening of the dough to determine the strength of the wheat flour. Finally observing the protein content helps to develop the reological properties. Mixolab is a modern equipment developed for controlling grain quality. The instrument determines the quality of dough and flour by exposing a sample to predetermined heating and cooling cycles while placing the sample under a deformation field. The data is collected as a set of strain-deformation graphs analyzed by an algorithm for analysis of the multi-graphic data structure. The method and analysis of the measurement results are based on the same principles as the Pétrinex dough test equipment (Mixolab: A New Approach to Rheology, 2013).

INFLUENCE OF STORAGE ON THE QUALITY OF WHEAT GRAINS

The quality of the technological processing of wheat for milling, baking and use of flour is determined by the quantity and quality of the protein and the state of the carbohydrate-amylase complex, thus enabling the starch deterioration and the alpha-amylase content to be verified. The determination of these characteristics in both the cultivation and the manufacturing process is carried out by common standardized methods, the effects of which are the main indicators of wheat quality crude protein, Falling Number and Zeleny sedimentation values. These factors influence the quality of milling, flour and bakery products in a key way (Hruskova and colab., 2004). After 5 months of storage in four different silos, (Mhiko, 2012) noted a decrease in grain moisture and hectometer mass, protein values and increase in the fall index.

METHODS FOR DETECTING INSECTS

The analysis of insects in stored products often requires them to be extracted from stored cereals. Extraction methods include sifting, flotation, aspiration and Berlese funnels. The yield of extraction varies depending on the species and development stage of insects. Hand sieves can be used for small samples and inclined or agitated sieves are better for larger samples. A thin layer of cereals and several shakes of a manual sieve or passing over a sloped or agitator sieve are required for a good process. A bent sieve can remove 88-97% of *Tribolium chestnut, Sitophilus oryzae* and *Rhyzopertha dominica* from a 25 kg wheat sample with two passes over the sieve, and most remaining insects are extracted with one to four more passes. A reduction test can remove 84-91% of *Cryptolestes ferrugineus* adult and 57-81% of larvae from a 1 kg sample. Agitator or suction sieves can eliminate similar percentages of *Sitophilus granarius*, *Oryzaephilus sulinensis* and *Cryptolestes ferrugineus*. A rotary screen can remove 100% of living and dead adults from the flour. The mechanism used can recognize >89 % of the six adult insect species that have developed in stored cereals (*Ahasverus advena, Cryptolestes ferrugineus, Oryzaephefishilus sulinensis, Rhyzopertha dominica, Sitophilusm granarius*, and *Tribolium chestnut*) in wheat samples and at least 50 % in maize weevil. In comparative studies, growth methods, ninhydrin and X-ray methods have shown the most realistic number of insects feeding internally in a sample unit (Fundamentals of Stored-Product Entomology, David W. Hagstrum Department of Entomology Kansas State University Manhattan, Kansas and Bhadriraju Subramanyam Department of Grain Science and Industry Kansas State University Manhattan, Kansas, 2006).

ADVANCED METHODS FOR DETERMINING INSECT INFESTATION

Infrared spectroscopy is a quick and accurate method of identifying insects, and also very important for grain growers, industry and exporters. This method is reliable for determining the quantity of insects. The infrared Fourier transform is another spectral method similar to infrared spectroscopy, which provides valuable information from spectrum development. Insects damage the quality of cereals by reducing the weight of cereals, nutritional ingredients, leaving traces of uric acid and holes on the surface of the grain. These changes explain the spectral variations of the infrared Fourier transform (Mishra, Srivastava, Panda and Mishra, 2018a, 2018b, 2018c). Electronic nose is a technique for rapid and accurate deterioration detection, reduces the time on the sample preparation phase and analysis interval (Mishra and colab., 2018a, 2018b, 2018c). All sensors responded to volatile compounds produced at the top of the instrument in a different way, making it necessary to have the most reliable volatile sensors. As an experimental test in stored wheat *R. dominica* was added to facilitate artificial infestation with variable intensity at four different storage intervals and was evaluated by the E-nose system for variation in quality, and in particular chemical composition (Mishra and colab., 2018a, 2018b, 2018c). The electronic nose consists of 18 metallic oxide semiconductor sensors, the resistance capacity of the entire sensor set has changed due to volatile products from infested wheat grain. Hybrid methods developed using the electronic nose were used to assess the multiplied number of insects, protein and uric acid concentration.

CONCLUSIONS

This overview presents some of the methods and equipment used in determining the quality of wheat. There has been an improvement over time in some methods and the patenting of other new procedures to make it easier to work. The manner we want to work is faster, and the results to be as accurate and precise as possible, all this has generated the implementation of new systems and the improvement of old ones. The quality of the products offered by the producers is essential for the consumers, therefore in the field of wheat quality we want to monitor the particularities of the cereals, because they pass on the quality of the resulting products. Modern methods and equipment for determining wheat quality are much faster, more accurate, and easier to perform, but are much more expensive.

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