[1.]Elisabeta PRISACARIU, [2.]Gabriel–Alexandru CONSTANTIN, [1.]Gabriel GHEORGHE, [1.]Ana ZAICA, [1.]Alin HARABAGIU, [1.]Melania CISMARU, [1.]Dragos DUMITRU

# FACTORS INFLUENCING THE SIEVING PERFORMANCE IN WHEAT MILLING PLANT: A REVIEW

[1.]National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry / ROMANIA
[2.]National University of Science and Technology POLITEHNICA Bucharest – Faculty of Biotechnical Systems Engineering / ROMANIA

**Abstract:** Flour is one of the consumable raw materials frequently used in the food industry for the production of various bakery and pasta products. Sieving is an essential process in the technological flow of wheat milling, the oldest and most widely used method of solid–solid separation, based solely on size difference. A sieve, defined as a surface containing a certain number of openings of equal size, is the basic working element for separating. This article presents the state of research on the importance of achieving the most efficient sieving as well as the factors that influence its performance. Aspects such as clogging of sieve meshes, wheat grain hardness, chemical composition of flour fractions depending on particle size distribution, the need to use a flow agent in the case of soft grain flours and the importance of calculating extraction coefficients on frames, on frame packages and on the entire plansifter compartment for a efficient sieving are presented in the paper.
**Keywords:** wheat flour, sieving process, particle size distribution, sieve

## 1. INTRODUCTION

Sifting in food and nonfood agroindustrial products is a unitary operation of great importance both at a business level and at an academic and research level, since the application sectors are quite wide, such as seed selection, flour classification, and mineral classification. It is probably the oldest and most widely used solid–solid separation method [1] and also one of the simplest methods of particle size classification in laboratories and industries in general [2], involving the separation of various size particles into two or more portions by means of screening surfaces. Size separation is also known as sieving, sifting, screening. The technique is based on physical differences between their size, shape and density [3].

The operation of particle separation is divided into two main categories, continuous and batch operations. In continuous operation, the particles are continuously fed into the separation unit during the whole separation process. This type of particle separation is usually called "screening". On the other hand, batch operation is used if the particulate material is charged only once. This kind of batch separation is commonly described by the term "sieving" [4].

In practice, sieving is performed more on the basis of experience and intuition than on a theoretical basis, with sieves being the basic working elements for separating solid particles by size [1]., where the process mainly takes place by separating the product into two parts, the larger particles remain on the upper sieve, and the other particles fall through the sieve meshes [2]. They are used both at industrial and laboratory scale for classifying particulate materials [1]. A sieve or screen can be defined as a surface containing a certain number of openings of equal size, and whose surface can be flat (horizontal or inclined) or cylindrical. These openings refer to the space between the individual wires of a wire mesh sieve and are related to the mesh number of the sieve, which is the number of openings per linear inch. Industrial sieves are made with metal bars, sheets, and perforated cylinders or with fabrics and woven wire. Materials for the construction of the sieves for separating food include stainless steel and nylon fabrics [5].

Considering that sieving is a method of separating particles based solely on size differences. In industrial sieving processes, solids are poured onto a perforated surface or sieve, which allows the


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

small particles, or "fines", to pass through and retain the larger particles, or "rejects". A sieve can usually only separate into two fractions, these fractions are called unspecified size fractions because, although the upper or lower limit of particle size is known, only the average particle size can be found, so the actual size is unknown but still approximate [2]. To achieve more efficient screening, a series of screens with decreasing mesh size is often used, also known as "cascade screens" [20] [6]. By arranging the screens with the largest openings at the top, a product of the desired size can be obtained and large particles can be returned to a grinding process [2].

According to the Scopus analysis, carried out by Sanchez–Suarez N. et al. in the paper [7], regarding the raw materials that are mainly subjected to the sieving process, at least 27% of the researched raw materials are sieved to obtain flour, 21% of which is wheat, 9% is corn, and rice corresponds to 14.63%.

In the agro–industry it is known that it is important to standardize products in order to offer customers the same quality and type of product, according to this, sieving becomes a unitary operation plus easy to use due to its structure and equipment does not require great academic knowledge, in addition, it allows obtaining the product with the above–mentioned characteristics [8]. For determining the particle size of wheat flour, ASABE Standard S319.4 (ASABE Standards, 2008) and AACC Standard 55–60.01 (AACC, 2011) are the most common methods followed [9].

## 2. MATERIALS AND METHODS

In the development of this paper, articles from specialized literature sources (ScienceDirect, ELSEVIER, ResearchGate, MDPI) were studied to determine the main aspects that must be considered to make the sieving process as efficient as possible, both from a technical and economic perspective.

At the industrial level, the main equipment used to separate the grinding fractions for the sieving process is the plansifter (Figure 1). At the laboratory scale, the standard ASAE procedure for particle size analysis of particulate materials also requires the use of a stack of sieves, such as the Ro–Tap sieve shaker (Figure 2) [10].

Figure 1 – Plansifter with eight compartments (4 x 2, placed back to back) [41].

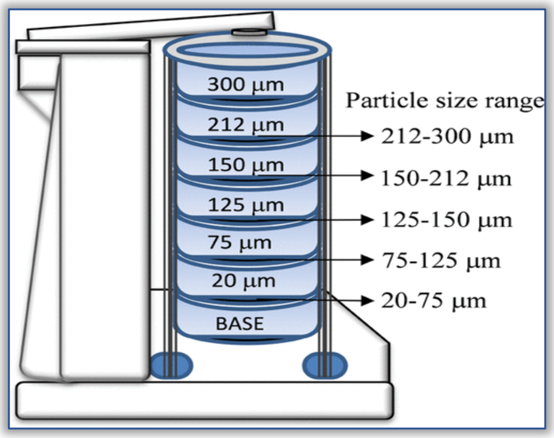


Figure 2 – Schematic of the sieve setup on a Ro–Tap sieve shaker [34].

The Plansifter accurately classifies (sifts and sorts) floury and grain products in wheat, rye and corn mills. It has a large screening capacity, sturdy frame and wooden or synthetic sieve stacks. The path of the grinding fractions on the sieve is shown in figure 3 [11]. The height of each sieve is a minimum of 55mm, but may vary depending on the volume circulated inside the sieve compartment.

## 3. RESULTS

Although sieving has played an important role in the study and processing of particulate materials, it has not received sufficient scientific attention [13]. The simplicity and familiarity of the process may explain this situation. Jezsó K., Peciar P. emphasize that, in reality, the sieving process is governed by multidisciplinary principles, from physics to applied fluid mechanics, which have been studied in numerous works [14].

Factors that affect the movement of individual particles and thus the efficiency of the process can be divided into three groups [15].

1. Factors that are related to the properties of the raw material, such as:
   - particle size distribution;
   - particle shape;
   - moisture content;
2. Factors that depend on the design of the equipment used and include:
   - shape and size of of the screen openings;
   - type and material
   - inclination angle of the screening surface
   - vibration mode (linear, circular, elliptical)
   - direction
   - vibration amplitude
   - and frequency
3. Factors characterizing the sieving/screening process itself, such as:
   - mass flow rate (in the case of a continuous process) or the amount of material fed (in the case of a batch process)
   - screening duration
   - and the influence of particle layer thickness [15], [13], [16], [17], [18], [19], [6].

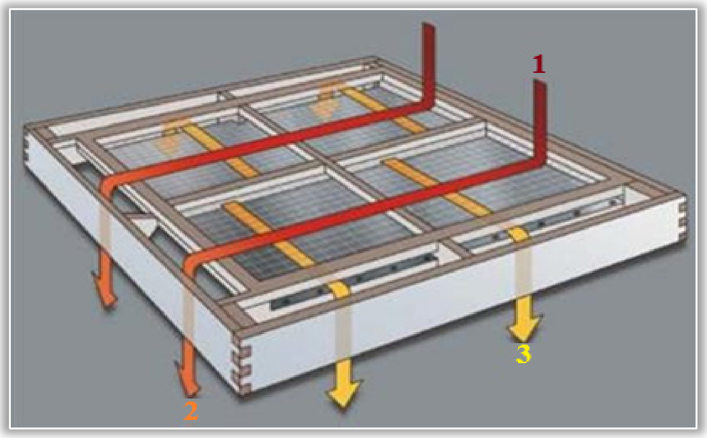

Figure 3. The path of the grinding fractions on the sieve. 1 – grinding fraction that feeds the frame; 2- rejected fraction; 3 – sieved grinding fraction [12].

The sieving/screening process is also accompanied by blinding of the screen apertures, which is mainly caused by particles with sizes close to the mesh size. In order to maximize the efficiency as much as possible, an optimization of the entire process is necessary, but it is important to note that increasing the amount of material fed negatively affects the mesh wear [15].

Of all the elements of the sieving operation, sieve blinging is considered the most important and direct controlling factor. Sieving blinding occurs when particles become stuck and remain in the sieving mesh. This phenomenon results in a reduction in the effective screening area, resulting in reduction of sieving rate (sieving performance or capacity) and the degree of sharpness of particle separation (sieving efficiency) [13], [16], [18], [20].

The use of a plansifter as the primary method for analyzing the particle size distribution of wheat flour [21] can be inaccurate, especially for fine particles below 100 microns. This problem becomes particularly pronounced when analyzing soft wheat flour [9], [22]. Thus, for the analysis and distribution of fine particles, the laser diffraction method is suitable [23], [24].

In paper [4]. Alkhaldi and Eberhard presents a numerical model for studying the particle screening process in a rotating tumbling vertical cylinder using the discrete element method that considers the motion of each particle individually. The diagram of the process of sieving proposed in the paper is presented in the figure 4.

Due to the weaker bond between starch and protein, milling of soft wheat results in smaller particle sizes than durum wheat [25], [26]. The difference in hardness values results from hard wheat having starch granules that are deeply embedded in the protein matrix of the kernel’s endosperm, while soft wheat contains voids in the endosperm protein matrix in which the starch granules are weakly embedded [27]. In addition, Hareland et al. [28] reported that soft wheat flour has high


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

cohesion and clogs sieve meshes. To overcome the cohesive forces between particles during size measurement, the ASABE S319.4 standard suggests the use of flow agents (ASABE Standards, 2008) [9]. A flow agent added to the ground grain would help move particles through the screens and potentially result in a finer particle size and greater particle size standard deviation than results from samples analyzed without a flow agent [29].

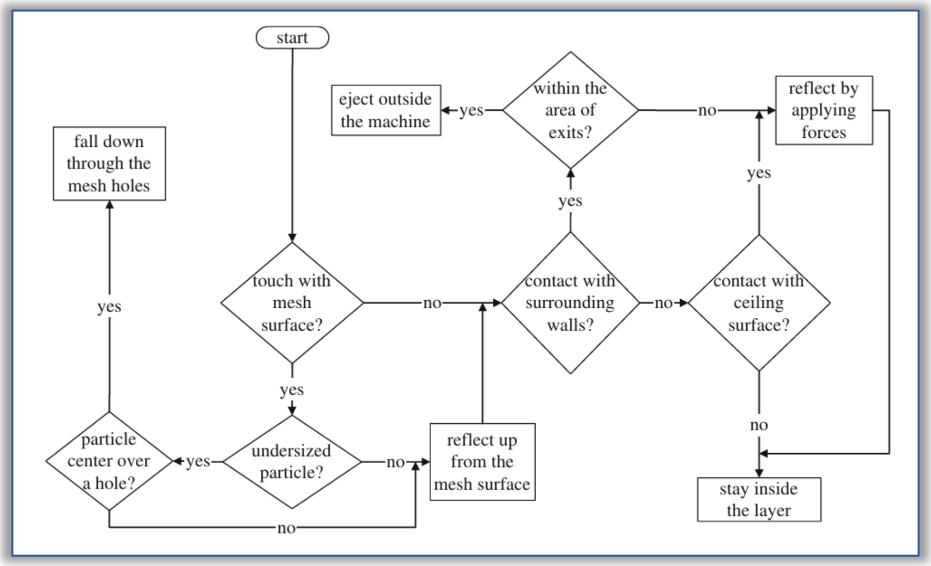


Figure 4 .The diagram of the process of sieving [4].

In [9], Patwa A. et al. determined the average particle sizes of flour from two different grades of wheat, namely: hard red winter (HRW) and soft white (SW), without a significant difference in diameter, at sieving times of 8, 10, 12, 14, 16 and 18 min, using a Ro–Tap sieve shaker. The particle size measured by sieve analysis was compared with the size measured using laser diffraction. Also, sieve sieving was repeated for both classes of flour with the addition of a quantity of flow agent.

It was observed that by laser diffraction there was no significant difference in the average particle sizes of the two types of flour. However, when compared to the results obtained by sieve application (with or without flow agent), a significant difference in particle sizes was observed between the two methods, sieving and laser diffraction, but also between the two types of wheat flour.

SW flour has a slightly wider distribution, due to the presence of disassociated starch granules, which is a consequence of starch–protein disaggregation compared to HRW flour.

The use of 0.5 g of flow agent for SW flour was not sufficient because it did not influence the average particle size and size distribution. A more accurate size distribution for SW flour was obtained by adding 2.5 g of flow agent. The difference between at a sieving time of 14 minutes was 509 μm for SW flour with 2.5 g flow agent and 20.65 μm for HRW flour with 0.5 g flow agent. The cumulative particle size distribution for durum and soft wheat flour showed a more uniform distribution for HRW flour, indicating that the particle sizes are more evenly distributed.

The sorting of flour into different size fractions of wheat flour using sieves causes the sorted fractions to differ not only in particle size but also in chemical composition [21], [30], [31]. These properties have an effect on the quality of the flour and ultimately on its performance in finished products [32], [31], [33].

Although the particle size of flour can be reduced by regrinding a sample, further reduction of flour particle size by milling is accompanied by an increased level of starch damage, which negatively affects the performance of flour in many end products [35]. Thus, fractionated flours are characterized not only by differences in chemical composition and physical properties, but also by minimal starch damage [33].

The chemical composition can affect the dough kneading properties of flour (water absorption rate), gluten network formation, dough properties (hardness, viscosity, elasticity, extensibility, plasticity, water retention, etc.) [35]. The major components of wheat flour are proteins (approximately 10%–12%) and starch (approximately 70–75%), and the minor components are polysaccharides (approximately 2–3%) and lipids (approximately 2%) [36].

Lin et al. [35] used sieving to divide flour obtained from a mixture of three wheat varieties into eight size fractions with median particle size (d50) ranging from 13.6 to 42.4 μm. They demonstrated that as the flour particle size decreased, the starch content and the degree of starch damage increased. In contrast, the lowest protein content was observed in the fraction with a d50 of 17.3 μm, while the highest protein content was found in the fraction with a d50 of 26.3 μm. Furthermore, the flours varied not only in protein content but also in protein type. The finest flour fractions showed the highest amounts of albumins, gliadins, and glutenins [35].

The efficiency of the screening process can be determined by finding the amount of screening particles that are rejected by the sieve along with the rejection fraction, on each sieve of the equipment. The expression of the screening process through mathematical relationships has been carried out worldwide by several researchers, who have proposed various models that are more or less close to reality. These models were verified experimentally and the coefficients of mathematical relationships and the degree of correlation with experimental data were determined. The extraction coefficient shows the degree of separation of the sieve particles from the initial material feeding the sieve or sieve pack at a given time, in other words, the extraction coefficient represents the ratio between the amount of sieved material and the amount of material fed.

In the paper [37], Voicu G. et al. presented a calculation algorithm for the extraction coefficients on frames, on frame packages and on the entire plansifter compartment using experimental data obtained at first plansifter compartment of a wheat milling plant with a capacity of 100 t/24 h. Within a plansifter compartment, frames are disposed on packages (each having the same characteristics of fabric). Within the package frames, generally work in series (consecutive), while the frame packages can work both in parallel and in series. The interior scheme of the analyzed plansifter compartment and calculation scheme the coefficients of extraction of the frames and packages at the same plansifter compartment are presented in Figure 5.

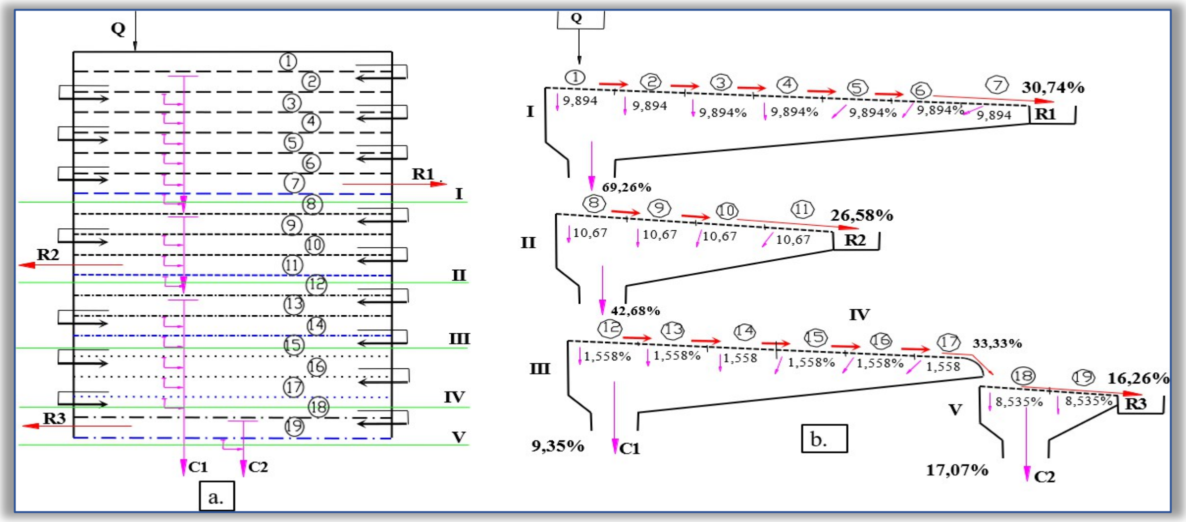


Figure 5. The interior scheme of the analyzed plansifter compartment (a) and calculation scheme the coefficients of extraction of the frames and packages at the same plansifter compartment (b) . Q – feed debit of plansifter compartment; R1, R2, R3 – the refusals of the compartment; C1, C2 – the sifting of the compartment; I. . . V – the number of package [37].

## 4. DISCUSSION

Given the importance of sieving for the food industry and beyond, trying to have the most efficient sieving is the most important aspect to consider.

The efficiency of the sieving process determines both the quality of particle separation and the associated operational costs, thus achieving an increase in productivity in both the food and feed industries.

Reducing the clogging effect of the sieve meshes, which is particularly necessary for soft wheat flour, could reduce energy and time consumption because the sieve meshes being free, the granular material passes through easily and thus the amplitude of the vibrations required is reduced. At the same time, the process is also more efficient from a technical point of view, since it is no longer necessary to stop the equipment frequently for cleaning, thus minimizing accidental grinding losses.

When sieving highly cohesive products it is necessary to clearly indicate the use of a flow agent, as well as the quantity required for the most efficient sieving of these products.

Another important aspect to consider when sieving a grist fraction is that if they have not been screened correctly due to process inefficiency, re–milling by further reducing the size of the flour particles through milling is accompanied by an increased level of starch damage, which negatively affects the performance of the flour in many final products.

In the context of trying to solve certain environmental problems, the possibility of using biodegradable materials for the construction of supporting elements of plansifters has also been studied. This encourages more experimental research to be carried out in this direction.

## 5. CONCLUSIONS

In conclusion, the sieving process holds significant importance for the food industry and beyond, and its efficiency directly influences the quality of the final product, production costs, and the sustainability of operations. In addition to technical advantages, such as reduced sieve mesh clogging and achieving a uniform particle size distribution, an efficient sieving process brings notable economic benefits: reduced energy consumption, minimal raw material losses, and a more stable production flow.

**References:**

[1] Sultanbawa, F. M.; Owens, W. G.; Pandiella, S. S. A new approach to the predicting of particle separation by sieving in flour milling. 2001, Food and Bioproducts Processing, Volume 79, Issue 4, 2001, Pages 211–218, ISSN 0960–3085
[2] Foust, W. Principles of Unitary Operations. New York, NY: John Wiley and Sons, 1990.
[3] Jesny, S.; Prasobh, G.R. A Review on Size Separation. International Journal of Pharmaceutical Research and Applications, 2022, Volume 7, Pages 286–296.
[4] Alkhaldi, H.; Eberhard, P. Particle screening phenomena in an oblique multi–level tumbling reservoir: A numerical study using discrete element simulation. Granular Matter, 2007, Volume 9, Pages 415–429
[5] Velásquez, A. Practical Laboratories. Agroindustrial Technology: Unit Operations. Medellín: Uniremington, 2011.
[6] Allen, T. Particle size analysis by sieving. In: Powder Sampling and Particle Size Determination, Elsevier, 2003, Chapter 4, Pages 208–250.
[7] Sanchez–Suarez, N.; Orozco–Mendoza, G.L.; Zartha–Sossa, J.W.; Gafaro–Garcés, D.C.; Melchor–Cahuana, L.G.; Gonzalez–Tovar, C. Trends in Sieving and Its Applications in Cereals: A Literature Review. Frontiers in Sustainable Food Systems, 2022, Volume 6, Article 902147.
[8] Arndt, M.; Rurik, M.; Drees, A.; Bigdowski, K.; Kolhbacher, O.; Fischer, M. Comparison of different sample preparation techniques for NIR screening and their influence on the geographical origin determination of almonds (Prunus dulcis MILL.). Food Control, 2020, Volume 115, Article 107302.
[9] Patwa, A.; Malcolm, B.; Wilson, J.; Ambrose, K. Particle Size Analysis of Two Distinct Classes of Wheat Flour by Sieving. Transactions of the ASABE, 2014, Volume 57, Pages 151–159
[10] ASAE (American Society of Agricultural Engineers) Standards, Methods for Determining and Expressing Fineness of Feed Materials by Sieving, 2003, S319.3. St. Joseph, MI.
[11] *** https://www.buhlergroup.com/global/en/products/arenit_plansifter.html
[12] *** https://www.prillwitzgroup.com/pdf/plansichter–pc.pdf
[13] Leschonski, K. Sieve analysis, the Cinderella of particle size analysis methods? Powder Technology, 1979, Volume 24, Pages 115–124.
[14] Jezso, K.; Peciar, P. Influence of the Selected Sieving Parameters on the Sieving Efficiency of Material MCC Avicel PH102. Strojnícky časopis – Journal of Mechanical Engineering, 2022, Volume 72, Pages 77–88
[15] Goesaert, H.; Brijs, K.; Veraverbeke, W.S.; Courtin, C.M.; Gebruers, K.; Delcour, J.A. Wheat flour constituents: how they impact bread quality, and how to impact their functionality. Trends in Food Science & Technology, 2005, Volume 16, Issues 1–3, Pages 12–30.
[16] Roberts, T.R.; Beddow, J.K. Some effects of particle shape and size upon blinding during sieving. Powder Technology, 1968, Volume 2, Pages 121–124.


ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

[17] Brereton, T.; Dymott, K.R. Some factors which influence screen performance. In: M.J. Jones (Ed.), Tenth International Mineral Processing Congress, IMM, London, 1974, Pages 181–194.
[18] Apling, A.C. Blinding of screens by sub–sieve sized particles. Transactions of the Institution of Mining and Metallurgy, Section C, 1984, Volume 93, Pages C92–C94.
[19] Standish, N. The kinetics of batch sieving. Powder Technology, 1985, Volume 41, Pages 57–67.
[20] Barbosa–Cánovas, G.V.; Ortega–Rivas, E.; Juliano, P.; Yan, H. Separation and classification. In: Food Powders, Physical Properties, Processing, and Functionality, Kluwer Academic/Plenum Publishers, New York, NY, 2005, Chapter 10, Pages 247–270
[21] Dziki, D.; Krajewska, A.; Findura, P. Particle Size as an Indicator of Wheat Flour Quality: A Review. Processes, 2024, Volume 12, Issue 11, Article 2480.
[22] Dziki, D. The latest innovations in wheat flour milling: A review. Agricultural Engineering, 2023, Volume 27, Pages 47–162.
[23] Lyu, F.; Thomas, M.; Hendriks, W.H.; van der Poel, A.F.B. Size reduction in feed technology and methods for determining, expressing and predicting particle size: A review. Animal Feed Science and Technology, 2020, Volume 261, Article 114347
[24] Ahmed, J.; Mulla, M.Z.; Arfat, Y.A. Particle size, rheological and structural properties of whole wheat flour doughs as treated by high pressure. International Journal of Food Properties, 2017, Volume 20, Pages 1829–1842
[25] Bechtel, D.B.; Zayas, I.; Dempster, R.; Wilson, J.D. Size distribution of starch granules isolated from hard red winter and soft red winter wheats. Cereal Chemistry, 1993, Volume 70, Issue 2, Pages 238–240
[26] Pauly, A.; Pareyt, B.; Fierens, E.; Delcour, J.A. Wheat (Triticum aestivum L. and T. turgidum L. ssp. Durum) kernel hardness: II. Implications for end–product quality and role of puroindolines therein. Comprehensive Reviews in Food Science and Food Safety, 2013, Volume 12, Issue 4, Pages 427–438.
[27] Turnbull, K.M.; Rahman, S. Endosperm texture in wheat. Journal of Cereal Science, 2002, Volume 36, Issue 3, Pages 327–337.
[28] Hareland, G.A. Evaluation of flour particle size distribution by laser diffraction, sieve analysis, and near–infrared reflectance spectroscopy. Journal of Cereal Science, 1994, Volume 20, Issue 2, Pages 183–190
[29] Goodband, R.; Diederich, W.; Dritz, S.; Tokach, M.; DeRouchey, J.; Nelssen, J. Comparison of particle size analysis of ground grain with, or without, the use of a flow agent. Kansas Agricultural Experiment Station Research Reports, 2006
[30] Wang, L.; Flores, R.A. Effects of flour particle size on the textural properties of flour tortillas. Journal of Cereal Chemistry, 2000, Volume 31, Pages 263–272
[31] Toth, A.; Prokisch, J.; Sipos, P.; Sizeles, E.; Mars, E.; Gyori, Z. Effects of particle size on quality of winter wheat flour, with a special focus on macro– and microelement concentration. Soil Science and Plant Analysis, 2005, Volume 37, Pages 2659–2672
[32] Neale, M.E. Sieve analysis of particulates—a review and recommendation. Cereal Foods World, 1997, Volume 42, Pages 507–509.
[33] Hatcher, D.W.; Anderson, M.J.; Desjardins, R.G.; Edwards, N.M.; Dexter, J.E. Effect of flour particle size and starch damage on processing and quality of white salted noodles. Cereal Chemistry, 2002, Volume 79, Pages 64–71
[34] Yamazaki, W.T. Flour granularity and cookie quality: I. Effects of changes in granularity on cookie characteristics. Cereal Chemistry, 1959, Volume 36, Pages 52–59.
[35] Lin, J.; Gu, Y.; Bian, K. Bulk and Surface Chemical Composition of Wheat Flour Particles of Different Sizes. Journal of Chemistry, 2019, Article 5101684, 11 pages
[36] Goesaert, H.; Brijs, K.; Veraverbeke, W.S.; Courtin, C.M.; Gebruers, K.; Delcour, J.A. Wheat flour constituents: how they impact bread quality, and how to impact their functionality. Trends in Food Science & Technology, 2005, Volume 16, Issues 1–3, Pages 12–30.
[37] Voicu, G.; Constantin, G.; Ștefan, E.–M. Mathematical algorithm for calculating the coefficients of extraction of a plansifter compartment in wheat milling plant. UPB Scientific Bulletin, Series D: Mechanical Engineering, 2014, Volume 76, Pages 149–162.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665