Ultrasonically Improved Sieving of Food Materials for Manufacturing of Direct Expanded Extrudates

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Summary

Particle size distribution of raw materials plays an important role in extrusion process during direct expanded extrudates manufacturing. In most of the food industries all types of flours come in a production plant packed in bags with certain checkmarks that consist of average size of particles expressed in µm. That particle size range is very relative, because mostly it means that size of most frequent particles is expressed. During extrusion processing of corn flour and whey or soy proteins blends are interject, then it is very important to know precise particle size of the interjected blends. If it does not match, raw materials should be sieved and particular fractions separated.

To obtain the best fraction of corn flour for extrusion processing (200 – 450 µm), sieving was conducted in shaker "Analysette 3" with sieving times of 5, 10 and 15 minutes. For each of these three measurements an agglomerate creation was spotted, followed by the major remain of the sample at the mesh of 450 µm.

Sieving was repeated with aid of ultrasound (250 W), using power generator and by ultrasonic ring with transducer ("UIS 250 L") mounted on the sieves. Sieving was conducted again with sieving times of 5, 10 and 15 minutes, and variable amplitude of works of 25, 50 and 75% for ultrasound. Within each of these nine measurements a partial or complete agglomerate breakdown was achieved, and an optimal fraction for extrusion processing was acquired. For the desirable particle size fraction in range of 200 – 450 µm for extrusion, under the conditions of 10 and 15 minutes of sieving time with amplitude work of 75%, the most of the sample remained within desirable range (83,79% and 83.4%).

Key words

ultrasound, sieving, extrusion, corn flour

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Introduction

In food technology extrusion should be specified as a cooking-extrusion process with the goal of manufacturing crispy, well nutritionally balanced, expanded, tasty and voluminous products. There is no limitation for using main raw materials for this kind of products. However, cereals stand for a lot of products. Corn, wheat, rye and barley are very high placed in this chain (Garber et al., 1997; Brnčić et al., 2006). Beside dough characteristics, presence of water, pressure and many other various characteristics of manufacturing system, a particle size of inputted raw material play an important role in getting a final product with already mentioned properties. For instance, when raw material is enhanced with whey proteins or soy bean proteins (both concentrates) it is very important to be aware of differences between sizes of particles of main raw material (Guy, 1994; Brnčić et al., 2008a). If there is concern about that, raw material should be sieved. Corn flour as a raw material should be in size from 200 µm to 600 µm. For possible enrichment of final product with proteins, whose particle size is about 50 µm (whey and soy bean), than particle size of corn flour should be between 200 and 450 µm (Brnčić et al., 2008b). That kind of raw material is not easy to get from manufacturer and in most cases it is necessary to sieve it before extrusion.

Starch is main component of cereals and very sticky one (Onwulata and Constance, 2006; Brnčić et al., 2000). During sieving when particles collide these property causes creation of clusters or agglomerates commonly named "screen or sieve blocking" or "blinding". In Figure 1 typical "blinding" problem is presented.

When blinding occurs, the useful sieving area and sieves overall capacity are reduced, slowing down production levels. All flours are subjected to this problem. Most of the conventional methods are helpful for solving this problem down but limitation stands for the particles of 500 µm and bellow in size. When such a raw material is inputted in extruder without previous preparation, it can cause problems in expansion, quality and nutritional values of the product (Huber and Rokey, 1990; Guy, 1994). Manual cleaning of sieves with brushes results in cleaner sieving area but also with damaged, broken or twisted sieves. Many researches and companies developed various cleaning systems that use some type of mechanical devices. Example of these devices are cleaning discs or small balls, which during sieving are bouncing up and down, hitting the sieve and material to be sieved and shaking free any blockages. Mechanical forces produced during hitting, beside its main aim of deblinding i.e. breaking down of agglomerates, could seriously damage the sieves. Even larger problem could be if the balls or discs (after longer period of work) are not replaced and start to wear out. Small pieces of these units could fall behind and incorporate in sieved material. Another disadvantage with mechanical deblinding systems that is becoming increasingly relevant in today health and safety-conscious manufacturing environment is the noise these devices generate—noise levels of over 90 dB(A) have been recorded with some deblinding disc assemblies.

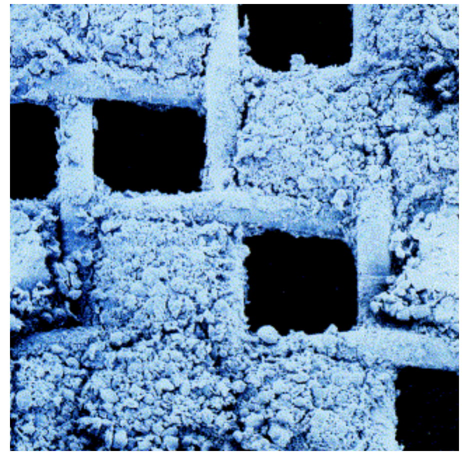

Figure 1. Sieve blocked with agglomerates (O'Connell, 2003)

Solution for this severe problem is use of power ultrasound for deblinding. Ultrasound waves as well as sound waves are mechanical vibrations in a solid or fluid. Ultrasound is the part of the sonic spectrum which ranges from 20 kHz to 10 MHz. It has been used in a many different technologies for a various industries. More and more in food industry, this utilizable technology is taking place as an analytical tool, or for the raw material modification before, during and after the manufacturing of food products (Mc Clements, 1995). Power ultrasound works with frequencies from 20 to 100 kHz. For ultrasonic deblinding a specially developed transducer was mounted on one empty ring (without mesh), and low frequency with high power output was provided for breaking down the surface tension, making the wires of the mesh free and as result of sieving needed fractions of food materials were achieved.

Material and methods

This work was carried out with corn flour purchased in local market. Chemical composition was declared by manufacturer: water – less than 15%; degree of acidity – up to 4.0. Trade description of flour was "Corn flour - germinated".

Sieving of corn flour as raw material for extrusion was conducted under different process conditions. The purpose of this was to obtain fractions of corn flour with optimal particle size (all particles bellow 450 µm in size and above 200 µm). Sieving was conducted and repeated multiple times, so long as it was necessary to obtain sample big enough for appropriate extrusion process. Sieving was carried out with following mesh diameters: 630, 500, 450, 355, 315, 280, 200 and 100 µm, with this order looking from the top of the device. Device for sieving in this work was sieving shaker "Analysette 3", model Pro, produced by "Fritsch", GMBH, Germany. This device is vertical, oscillating system for precise separation and classification of particle size, mainly used for fine powders and flours. Beside separation of fine particles it can also be used for particle size analysis, distribution and separation of dry

Table 1. Conditions of corn flour sieving without and with ultrasound treatment

Corn flour sieving without ultrasound treatment	
Sample	Sieving conditions
1 CF	Time of sieving, 5 minutes
2 CF	Time of sieving, 10 minutes
3 CF	Time of sieving, 15 minutes
Corn flour sieving with ultrasound treatment	
Sample	Sieving conditions
4 CF-US	Time of sieving, 5 minutes, amplitude of ultrasound 25 %
5 CF-US	Time of sieving, 5 minutes, amplitude of ultrasound 50 %
6 CF-US	Time of sieving, 5 minutes, amplitude of ultrasound 75 %
7 CF-US	Time of sieving, 10 minutes, amplitude of ultrasound 25 %
8 CF-US	Time of sieving, 10 minutes, amplitude of ultrasound 50 %
9 CF-US	Time of sieving, 10 minutes, amplitude of ultrasound 75 %
10 CF-US	Time of sieving, 15 minutes, amplitude of ultrasound 25 %
11 CF-US	Time of sieving, 15 minutes, amplitude of ultrasound 50 %
12 CF-US	Time of sieving, 15 minutes, amplitude of ultrasound 75 %

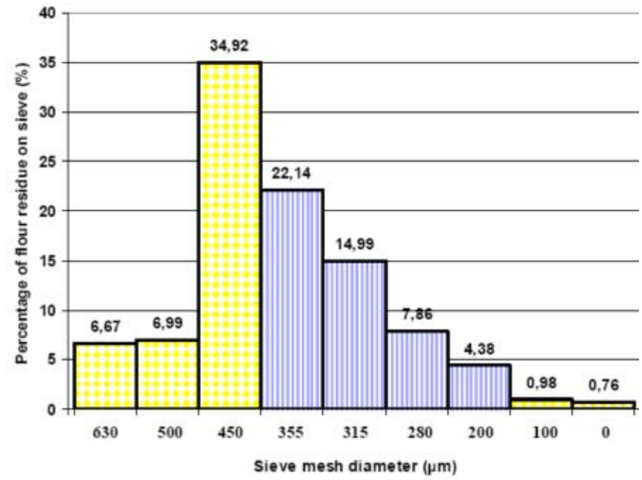

Figure 2. Results of sieving in time of 15 minutes (sample 3 CF)

particles, but also for the particles suspended in various liquids. Dependable of sample amount, sieves different in size could be used. Corn flour was processed under this set-up of device: shaking amplitude of 2.5 mm in time interval of five seconds (between each shaking cycle), and variable time duration of 5 , 10 and 15 min.

Afterward shaking was repeated for corn flour aided with power ultrasound accessory (max. 250W) ("UIS 250L", Hielscher Ultrasonics, GMBH). The system is composed of three main parts: generator, sieving tower set and ultrasonic processor with sonotrode mounted on sieving ring. Processor and power generator are operational with maximum power range of 250 W, variable amplitude in range of 20-80%, and unchangeable frequency of 24 kHz. Ultrasonic processor with sonotrode and maximum of eight laboratory sieves can be simultaneously mounted during measurement. Nine measurements were conducted in time duration of 5, 10 and 15 min, and variable ultrasonic amplitude of 25%, 50% i 75% (Table 1)

Results and discussion

A great number of researchers tried do determine optimal particle size distribution of raw materials for direct expanded extrudate production without or with addition of various types of proteins. Onwulata and Konstance (2006) found that optimal particle size distribution is 200-300 µm; while Gomez et al. (1991) suggested the range in 150-250 µm of inputted particles for this kind of product.

In this work, based on literature data, a task has been placed to get an optimal particle size for input of raw material (corn flour) that should be in range of 200-450 µm. To achieve this a separation of corn flour was conducted in shaker „Analysette 3" model Pro. Corn flour was sieved in periods of 5, 10 and 15 minutes, with sieving interval of five seconds.

The quality of direct expanded extrudate directly depends on proper choice of raw material (corn flour or corn meal) and also on particle size. It is known that profitability of processing is good when at least 75% of raw material particles are in desirable range of size (Brnčić, 2006). For a particular need of raw material, like in this research, that should be later used in processing of extrudates enriched with whey protein concentrate (WPC) or soy bean proteins (SBP), the study showed that particle size of corn flour was not match for the task. Results showed that for sieving of five minutes (Sample 1 CF) 55.58% of corn flour has been in desirable range and for sieving for 10 minutes even less (54.11%). In Figure 2, a diagram is presented for sample 3 CF; 49.37% of flour remained in the desirable range.

It is obvious that quite contrary effect of what was expected occured. Obtained results could be explained with formation of significant quantity of agglomerates that took place during sieving as result of particles collision (Barleta and Barbosa-Canovas, 1993). While collision is in progress, particles get stick to each other. Reason lies in starch stickiness. Starch is basic component of corn flour and after some time the agglomerates are created. Even with extended sieving (sample 3 CF) situation gets worse because larger agglomerates are created and as result a sieve is blocked or blinded.

To get an optimal fraction in size of 200 - 450 µm sieving was assisted with power ultrasonic equipment setup (maximum power of 250 W). Device consisted of ultrasonic transducer attached to the ring and power generator ("UIS 250", Dr.Hielsher). Ultrasonic ring with transducer was placed between sieve with smallest mesh diameter (100 µm) and base. Power generator created electric impulses of 50 Hz frequency that were converted in transducer in high energy mechanical signal with frequency of 24,000 cycles per second (24 kHz). This large amount of energy emitted in second penetrated through surface of the sieve and breaked down agglomerates, thus making possible regular separation of particles. Effect of deblinding was achieved. Three amplitudes of sonication were used in this work (25, 50 i 75%), combined with duration of 5, 10 and 15 minutes (Table 1).

On samples 4 CF-US, 5 CF-US and 6 CF-US, i.e., those which are treated first with ultrasound significant differ-

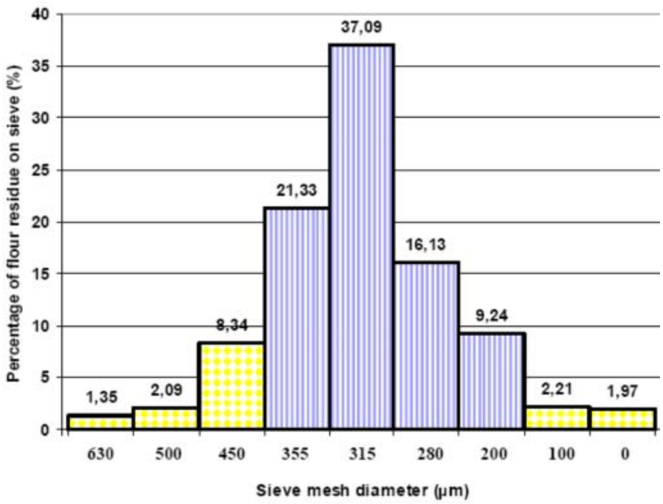

Figure 3.
Results of sieving in time of 10 minutes (sample 9 CF-US)

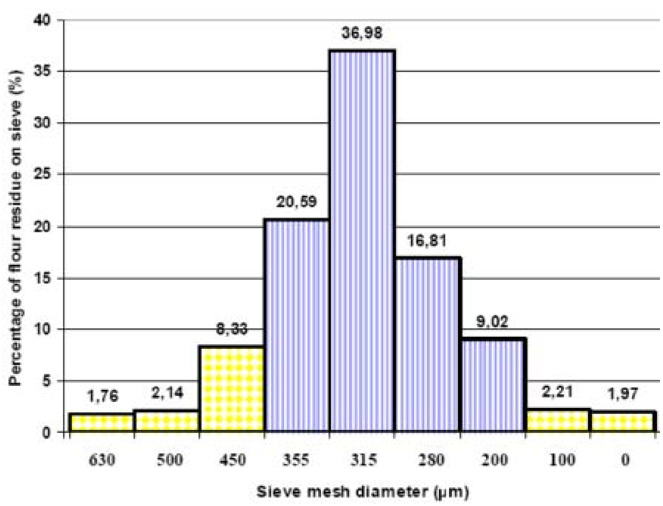

Figure 4.
Results of sieving in time of 15 minutes (sample 12 CF-US)

ences were evident compared with samples that are sieved without ultrasound assistance. Those were samples sieved in duration of five minutes. Since in this work only material that passed through sieve of mesh diameter of 450 µm, and remained on sieve in diameter of 200 µm was used in this investigation. Corn flour above and bellow that range was not further used for extrusion. Percentage of flour in desirable range showed severe difference between samples sieved with and without ultrasound, This already happened with sample 4 CF-US (68.95%), and then with samples 5 CF-US (74.2%) and 6 CF-US (79.57%) as well. Concerning settings presented in Table 1, an impact of ultrasonic amplitude on sieving i.e. separation results was evident. Yet, the result of sample 6 CF-US (79.57%) was within acceptable range and was acceptable for extrusion. For the samples marked as 7 CF-US (69.12%) and 8 CF-US (73.09%) a higher percentage of flour remained in desirable range while sample 9 CF-US (83.79%) completely fulfilled above mentioned requirement for extrusion (Figure 3). In this case, longer period of shaking (10 min.) with eligible amplitude (75%) gave an appropriate result.

There was a significant influence of ultrasound amplitude (75%) that managed to break down the most of the developed agglomerates created within first minute of the shaking. Afterwards, during remaining period of shaking power of ultrasound was too strong for the agglomerates to keep them in piece. Corn flour, rye flour and wheat flour were just some of the raw materials used for this kind of work and also chestnut flour (Sacchetti et al., 2004; Bounous and Giacalone, 1992.).

Finally results of the samples separated in duration of 15 minutes also showed progress and verified accuracy of method. Among them, sample 12 CF-US (Figure 4) was the most similar to 9 CF-US with 83.4% of the corn flour within wanted range.

Determination of particle size and separation of desirable fraction of corn flour is very important for extrusion processing with addition of various proteins. In this case sieving was used to separate fraction of corn flour that was according to the literature proper for such a processing. After sieving corn flour was mixed individually and with the whey proteins before extrusion took place. As the size of particles of whey protein concentrate is between 50-150 µm (Herceg et al., 2004a; Herceg et al., 2004b), also basic raw material (corn flour for this research) should be in sizes for maintaining proper mixing before processing in extruder and extrusion as well.

Garber et al. (1997) noticed that during extrusion processing bigger particles possessed smaller contact area with the extruder barrel than smaller particles, with less influence of heat in device and as consequence raw material was poorly processed. On the contrary, smaller particles were in better contact with interfaced area of the main inner parts of extruder (barrel, screw system). At the end smaller particles would be heated faster and acceptable conditions of extrusion could be established with better results (Zhang and Hoosney, 1998). Desrumaux et al. (1998) concluded that bigger particles of the corn flour give unwanted textural properties of direct expanded extrudates.

Conclusions

The results of sieving using ultrasonic setup showed justification of such a processing for corn flour. Without ultrasonic deblinding system sieves were blocked during first or second minute of the experiment. Samples sieved without ultrasound caused blocking of sieves from the top of the device, but most of blocking occurs on sieve of 450 µm. Using power ultrasound process of sieving was improved. This kind of research demonstrates that time of sieving and amplitude of ultrasound had important influence on particle sizing i.e. separation of desirable fraction. Sample sieved in duration of 10 minutes and 75% of ultrasonic amplitude had 83.79% of corn flour within range of 200-450 µm. In later research this fraction was used for high temperature-short time extrusion for manufacturing direct expanded extrudates enriched with whey protein concentrate. This method is adjustable also for particle size measurement of the powdered materials in variety of industries.

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