Feed particle size evaluation: conventional approach versus digital holography based image analysis

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ABSTRACT - The aim of this study was to evaluate the application of image analysis approach based on digital holography in defining particle size in comparison with the sieve shaker method (sieving method) as reference method. For this purpose ground corn meal was analyzed by a sieve shaker Retsch VS 1000 and by image analysis approach based on digital holography. Particle size from digital holography were compared with results obtained by screen (sieving) analysis for each of size classes by a cumulative distribution plot. Comparison between particle size values obtained by sieving method and image analysis indicated that values were comparable in term of particle size information, introducing a potential application for digital holography and image analysis in feed industry.

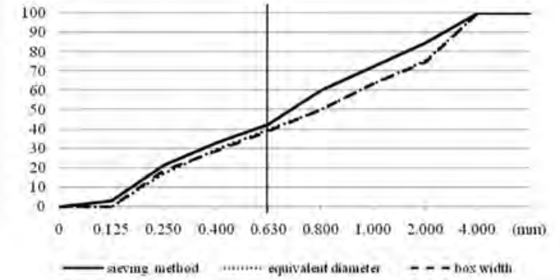
Key words: Feed, Particle Size, Image Analysis.

Introduction - Feed particle size plays an important role in improving the efficiency of feed utilization, and, as a consequence, on animal performances. Feed particle size influences the interaction with digestive enzymes, voluntary intake, as so as some technological properties of feedstuffs (stability, homogeneity and ingredients segregation). The particle size measure of bulk material in feed industry is usually performed by classical sieving analysis based on the use of electromagnetic sieve shakers. The basic analytical method involves stacking sieves (usually 8) on top of one another in ascending degrees of coarseness, and then placing the test powder on the top sieve. The nest of sieves is subjected to a standardized period of agitation, and then the weight of material retained on each sieve is accurately determined. The test gives the weight percentage of powder in each sieve size range. The size parameter involved in determining particle size distribution by analytical sieving is the length of the side of the minimum square aperture through which the particle will pass. Beside sieving, alternative approaches can be suggested (Melcion, 2000; Shekunov *et al.,* 2007). Image analysis, for instance, is becoming a wide adopted approach in food and pharmaceutics industries but it can also be adopted in feed manufacture as rapid and high automated approach, for example to quality control. This method is more informative than sieving and can provides further useful information about other physical (geometric) properties of feed ingredients. From this point of view measuring devices based on digital image capture and processing could offer advantages providing both determination of particle size and particle shape in fast and accurate manner. In light of this we have evaluate the application of image analysis approach based on digital holography in defining particle size in comparison with the sieve shaker analysis as reference method.

Material and methods – One-hundred grams of a ground corn meal were analyzed, as in a previous experiment (Campagnoli *et al.,* 2008), by a sieve shaker Retsch VS 1000 (Retch GmbH Rheinische Straße 36, 42781 Haan, Germany) equipped by a set of eight sieves (Ø mm 4.0; 2.0; 1.0; 0.8; 0.63; 0.4; 0.25; 0.125, respectively). Particle size was reported in terms of geometric mean diameter as described by ASABE (American Society of Agricultural and Biological Engineers). Particles resulted fractioned into nine different classes (eight fractions from each sieve plus one fraction from the plate on the bottom). Afterward, the same sample was analyzed through digital holography approach. A large collimated laser beam was sent through the region of space where the sample (feed particles) was let dropping. Since a few particles were present in the beam at a time, the main fraction of the light passes undisturbed, while the smaller fraction was diffracted along the direction of the impinging light. The diffracted light mixed with the main undisturbed beam, and the interference pattern formed onto the plane of a multipixel sensor (CCD) was recorded. By devising the principles of optical holography, the image of each particle was reconstructed irrespectively of its position. The reconstructed images, containing a total of 1773 particles, were then processed by an image analysis software (Image pro Plus 6.3 Media Cybernetics Inc., Silver Springs, USA). For each particle the image analysis software provides automatically 14 geometric descriptors (axis major; axis minor; diameter maximum; diameter minimum; diameter mean; radius maximum; radius minimum; size length; size width; box width; box height; feret minimum; feret maximum; feret mean), related to diameter, width and height of an non-regular shape object. Measurements were expressed in millimetres. As further descriptor, the equivalent diameter (diameter of a circle with equivalent area as the particle) was calculated by the formula $D=2\bullet(AREA/\pi^{0.5})$ suggested by Olaisen (Olaisen *et al.* 2001) (AREA was automatically obtained by the image analysis software). D was included into the set of descriptors due to the fact that it is the most frequently adopted parameter to define particle size measured by image analysis approaches (Melcion 2000; Shekunov *et al.,* 2007). Mean value and geometric standard deviation (GSD) of the 15 descriptors from all the 1773 particles obtained by digital holography were compared with particle size value and GSD obtained by sieving analysis. Afterward, the 1773 values for each of the 15 descriptors from digital holography were splitted into 9 classes, as the same case of sieving analysis (from >4.0; >2.0; >1.0; >0.8; >0.63; >0.4; >0.25; >0.125; <0.125 mm, respectivelly). Particle size from image analysis were compared with results obtained by sieving analysis for each of size classes by a cumulative distribution plot assuming that all particles in a size class had the same thickness and that thickness increased proportionally to the particle size. Ground corn meal density of 1.4g/cm^3 has been used as reference value (ANSI/ASAE S319.3 FEB03).

Results and conclusions – Average values of the 15 descriptors from the 1773 particles obtained by digital holography were compared in Table 1 with particle size obtained by screen analysis. Box width (width of the object bounding box), feret mean (average caliper (feret) length), box height (height of the object bounding box) resulted the three descriptors more similar to sieving method result. GSD of each parameter from image resulted larger than that from sieving method. Furthermore, the equivalent diameter value, the parameter

Figure 1. Size classes cumulative distribution plot. Comparison among particle size by sieving method vs image analysis equivalent diameter and box width. X axis: particle dimension (mm); Y axis: cumulative percentage.



most frequently adopted to define particle size obtained by image analysis, resulted the 8th of the 15 descriptors studied. According to both, the ranking of different image analysis descriptors and the reference one, box width (the descriptor with mean value more similar to sieving method result) and equivalent diameter (the most frequently cited in bibliography) were selected and graphically compared for each of size classes, with data obtained by sieve method (Figure 1). The resulting cumulative distribution plot showed that even if equivalent diameter mean value was closer than box width to sieving method results, the curves representing the two descriptors from image analysis were substantially overlapped. By contrast, when image analysis was compared with classical sieving some differences have been observed at 0.630-4.000 mm sieve opening, while slightly differences have been observed at small sieve opening (0.125-0.630 mm). Therefore it can be concluded that the two methods are comparable in term of particle size information when applied to ground corn meal, introducing a potential application for digital holography and image analysis in feed industry when data will be confirmed by further investigations performed with a larger samples set including different feed matrices at different granulometries.

Table 1. Comparison of particle size values differences between sieving methods and image analysis based on digital holography; DGM: Geometric Mean Diameter; GSD: Geometric Standard Deviation.

		DGM	GSD				DGM	GSD	
	Sieving Method	0.314	0.533			Sieving Method	0.314	0.533	
		Average (mm)	GSD	Difference			Average (mm)	GSD	Difference
	Descriptors:					Descriptors:			
1	Box Width	0.325	0.732	(-) 0.012					
2	Feret (mean)	0.300	1.086	0.014	9	Diameter (mean)	0.256	0.809	0.057
3	Box Height	0.289	0.770	0.024	10	Size (width)	0.229	0.980	0.085
4	Axis (major)	0.349	0.673	(-) 0.036	11	Feret (min)	0.220	1.030	0.094
5	Diameter (max)	0.352	0.682	(-) 0.039	12	Axis (minor)	0.209	0.959	0.105
6	Size (length)	0.357	0.722	(-) 0.043	13	Radius (max)	0.193	1.842	0.120
7	Feret (max)	0.363	0.713	(-) 0.049	14	Diameter (min)	0.165	1.099	0.149
8	Equivalent diameter	0.260	0.801	0.054	15	Radius (min)	0.064	2.379	0.250

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