A research review on coarse grain micronization

Fedor Kipriyanov1*, Petr Savinykh2, Alexey Aleshkin3, and Alexey Isupov2

1Vologda State Dairy Farming Academy named after N.V. Vereshchagin, 160555 Vologda, Molochnoe, Russia
2North-East Regional Agricultural Scientific Centre, 610007 Kirov, Russia
3Vyatka State University (FGEI HPE “VyatSU”), 610000 Kirov, Russia

Abstract. This article gives an overview of research on grain micronization and the principal research areas that have been carried out in this respect. The results of the effects of infrared radiation on fodder grain used in animal feeding are presented. It is stated in most of the researches that micronization causes destruction of grain molecular structure, decreasing its hardness, partially changing amount of starch, which positively influences on absorption of grain treated by infra-red irradiation. The main lines of research into the micronization process are formulated.

1 Introduction

Due to technical progress and improvements in technology and equipment, the concept of micronization was originally interpreted as heating by infra-red radiation using lamps. Although IR heating predominates in the micronization process, results in changes of structure and properties of treated grains similar to IR heating can be achieved by other means. From the thermophysical point of view infra-red radiation possesses any body which temperature is higher than absolute zero. This concept is the basis for infra-red micronization, where IR radiation from a heat source is transferred to the treated grains in a non-contact manner.

2 Methods

During the review of research on micronization of coarse grain standard methods of literary search were used, namely, the publications in periodical and specialized literature of the leading scientists who have studied the problems of micronization of grain material were studied. Methods of analysis, comparison of generalization and concretization were used, which allowed to draw conclusions on the main directions and results of research in the field of micronization.

3 Results and Discussion

* Corresponding author: kipriyanovfa@bk.ru
Electrical tube heaters (TEH), quartz halogen and carbon lamps can be used as sources of IR radiation whose emission spectrum most often lies in the near field ($\lambda=0.9–2.5 \, \mu m$, $T = 2900 - 890 ^\circ C$) of a light spectrum [1, 2]. Gas-fired radiant burners, usually of the panel type, used to increase the impact area, in which the heat source is the combustible gaseous fuel. A promising and practically free source of heat in gas-fired micronizers can be generator gas, obtained e.g., from the same waste products from a grain cleaning plant or from parallel technological lines of agricultural production. In recent years, electromagnetic influence on grain, causing its heating and destruction, has been used rather intensively. In particular, the use of electromagnetic field of ultrahigh frequency has a number of advantages, namely, it does not require a significant area for equipment, allows reducing the amount of anti-nutritive substances in grain by 20-25%.

The purpose of micronization is to increase the nutritive value of feed by transferring starch into easily digestible form and increasing its amount and, accordingly, the metabolic energy, improving digestibility by breaking molecular bonds and accelerating the absorption of nutrients, disinfecting the grain (it has recently been mentioned quite often) reducing anti-nutritive substances in the grain, such as pentosans in rye and trypsin in soya.

Micronization is one of the most effective methods of preparation of feed. Using micronised grains in ration can increase weight gain of weaned piglets up to 15.3% and decrease feed expenses up to 12.7% [3]. At the same time micronization allows the destruction of pathogenic microorganisms in the grain, as the maximum temperature for thermophilic microorganisms is of the order of 70-80\(^\circ\)C. Some studies carried out in the field of grain disinfection give the following results: barley micronization with a duration of exposure of 30s the degree of disinfection of surface microflora is 99.7%, while deep microflora is destroyed by 98% [4]. It is also noted that at an exposure time of 90s the microflora is completely destroyed, with aflatoxin B1 being reduced to zero. The impact of IR radiation gives high gustatory qualities and pleasant smell of grain that positively influences the edibility of fodder. Adding micronized grains to the fodder mixture enabled to increase the consumption of ration by regeneration heifers aged 4-6 months up to 8.6% [4].

Experience in the industrial use of infrared heat treatment units for grain and cereals has revealed at least three problems, generally typical for this type of operation:
1. Low thermal efficiency. If, ideally, to heat one kilogram of dry grain by 100\(^\circ\)C is needed about 50 kWh, the best proposed design consumes about 130 kWh (efficiency coefficient = 0.26). When electricity prices are low, this is acceptable, but as they increase, it may become a constraint. However, it should be noted that this figure depends considerably on the heat treatment modes.
2. limitation of the heating rate associated with thermal conductivity and the formation of temperature gradient in the thick product layer, and, as a consequence, limitations on the specific capacity of installations.
3. heterogeneity in the quality of treatment of individual grains at the outlet of the installation due to the variability of thermal physics and thermo-radiation characteristics of grains and the heterogeneity of heating conditions caused by the uneven irradiation field on the surface of the monolayer in the treatment zone.
4. Placing the product in a monolayer does not reduce the specific production area.
5. Inertia in the cooling process when using ceramic IR emitters. Unauthorised power cuts and high temperatures in the treatment area can cause a fire hazard [1, 2].

The above disadvantages lead to research into combinations of IR irradiation and other treatment methods, most commonly humidification and steam treatment.

There are more than 10 big firms all over the world engaged in micronization of grain raw materials, some of them dating back to the nineteenth century. And more than 90% of them are engaged in the production of feed just for animals (Table 1) [5, 6].
Table 1. Companies active in the micronization industry

<table>
<thead>
<tr>
<th>№</th>
<th>Name of company</th>
<th>Country of manufacturer</th>
<th>Since</th>
<th>Products</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I'Anson quality feeds</td>
<td>UK</td>
<td>1900</td>
<td>Micronized-flaked barley and maize</td>
<td>All animals (Ruminants, equine, poultry and pet)</td>
</tr>
<tr>
<td>2</td>
<td>Jones Feed Mills Ltd</td>
<td>North America</td>
<td>1930</td>
<td>Micronized flaked soybean, corn, barley, wheat and oat</td>
<td>All Livestock and Pig</td>
</tr>
<tr>
<td>3</td>
<td>Villamayor</td>
<td>Spain</td>
<td>1934</td>
<td>Micronized flour</td>
<td>Human</td>
</tr>
<tr>
<td>4</td>
<td>Chamwood milling</td>
<td>UK</td>
<td>1960</td>
<td>Micronized linseed, soya bean, wheat meal and hempseed meal</td>
<td>All Livestock and Pig</td>
</tr>
<tr>
<td>5</td>
<td>Virbac</td>
<td>Australia</td>
<td>1968</td>
<td>Micronized com</td>
<td>Horse</td>
</tr>
<tr>
<td>6</td>
<td>Micronizing Company (UK) Ltd</td>
<td>UK</td>
<td>1971</td>
<td>Micronized cereal flakes (barley and com), soya, oil seed, linseed, pea and Cocoa bean</td>
<td>Human, Ruminants, Horse, Poultry, Pig and Pet</td>
</tr>
<tr>
<td>7</td>
<td>Masham micronized feeds</td>
<td>UK</td>
<td>1974</td>
<td>Micronized-flaked barley and maize</td>
<td>All animals (Ruminants and Non-ruminants)</td>
</tr>
<tr>
<td>8</td>
<td>Eobank</td>
<td>Australia</td>
<td>1978</td>
<td>Micronized flaked barley, maize, lupin, tie beam, beet</td>
<td>Horse</td>
</tr>
<tr>
<td>9</td>
<td>Micronized Food Products</td>
<td>UK</td>
<td>over 30 years ago</td>
<td>Micronized (flake, whole, meal) barley, wheat, maize, peas, beans, rice, linseed and soya</td>
<td>Human, Livestock, Pet, Poultry and wild Bird</td>
</tr>
<tr>
<td>10</td>
<td>InfraReady Products Limited, Saskatoon, SK</td>
<td>Canada</td>
<td>1994</td>
<td>Micronized grains, legumes and oil seeds</td>
<td>Human</td>
</tr>
<tr>
<td>11</td>
<td>Capstone. HORSE FEED</td>
<td>South Africa</td>
<td>2004</td>
<td>Micronized maize and barley</td>
<td>Horse</td>
</tr>
<tr>
<td>12</td>
<td>Mi-Feed</td>
<td>Australia</td>
<td>n.f.</td>
<td>Concentrate mixture with micronized grains</td>
<td>All livestock classes</td>
</tr>
<tr>
<td>13</td>
<td>Morton nutrition</td>
<td>Australia</td>
<td>n.f.</td>
<td>Micronized lupin, maize, barley, naked oat,</td>
<td>Horse</td>
</tr>
<tr>
<td>14</td>
<td>Faravadaneh Ferdowsi Mashhad</td>
<td>Iran</td>
<td>2018</td>
<td>Concentrate mixture with micronized grains</td>
<td>All livestock classes</td>
</tr>
</tbody>
</table>

While in Russia, efforts in grain micronization are concentrated in research institutes. That, of course, would not preclude wider application of micronization of grain raw materials in production of products for humans. However, despite the significant benefits of micronized grains its production and use for the needs of feed production in agriculture is not widespread enough. The great interest of foreign producers in the processing of fodder is due to the fact that to date, grain is the main energy component of the fodder base of livestock production. Considering the high cost of the transport component, especially when imported from other regions [5]. Consequently, grain processing should be aimed at obtaining the maximum amount of energy from it, taking into account the economic component of efficiency of processing. The traditionally used mechanical processing of grain, such as crushing or dry
conditioning, does not guarantee effective and healthy starch digestion in the gastrointestinal tract. Therefore, the use of thermal treatment methods of grain to maximise the absorption of nutrients by the rumen microorganisms and the animal in general is relevant [6]. Micronization is a fast (30-90 s) thermal treatment using infrared radiation (IR) [7] and has great potential for use in the feed industry due to its simple design and operation [8].

Most often, the grains are heated by infra-red radiation as they move along the inclined or horizontal surface of the vibrating conveyor. In this case, vibration ensures that the grains rotate in relation to the infra-red radiation source, providing uniform heating. The use of other conveyors, on the other hand, requires additional shaking devices to ensure the rotation of the grains. It should be noted that when considering the design of micronization plants, little attention is usually paid to such elements as the feeder, exfoliator, and especially the cooler, which determine the safety of plant operation.

When evaluating the effect of micronization on grain properties, one of the most important values is the hardness of grain after treatment, so [9] evaluated the effect of micronization on grain hardness examining three varieties of wheat, including Sceptre, Laura and Kansas. The study showed that micronization decreased kernel hardness in Sceptre and increased in Laura and Kansas. The diversity of the results obtained calls for further investigation of the effect of micronization on grain hardness.

In a study [8] using a scanning electron microscope it was observed that starch granules increased in size several times from 2 to 25µm in untreated grains and up to 50µm in micronized grains. When starch is gluesterized by heat treatment, the molecular ordering in the starch granule is disrupted, leading to greater starch digestibility in vivo [10].

There is no effect of micronization on the chemical composition of barley grain [8]. Similarly, [11] also found that gross energy, crude protein, total fat did not change with micronization, however, total starch content increased by 13.47% and 9.09% when exposed to IR in barley grain for 10 and 35 s respectively or decreased by 3.9% when treated for 13 s compared to raw barley. There is also evidence that micronization can reduce tannin levels by 26.79% and 16.67% in high and low tannin sorghum compared to raw seed, respectively [12]. A recent study confirmed that since total phenolics, condensed tannins, trypsin and chymotrypsin inhibitor activity in holo-grain barley were significantly reduced by micronization [13].

In evaluating the digestibility of micronised maize grain, it was found that maize starch digestibility showed an improvement of 74.16%, 59.46%, 41.67%, 26.09% and 20.62% in micronised maize compared to raw maize for 2, 4, 8, 12 and 16 hours of incubation respectively [12].

As described in this study, the soluble starch fraction was reduced in all grain types due to micronization. There was evidence that during the desired infrared treatment time (60-120 s), the non-degradable crude protein of barley in the rumen could be digested in the small intestine to a greater extent than that of untreated grain. This event can lead to the release of glistered starch that has left the rumen (due to the reduced rate of decomposition in the rumen), resulting in more starch digestion in the small intestine and further less starch entering the large intestine for further fermentation. Thus, it can be assumed that micronization of grain has at least two advantages for ruminants: firstly, the rate of starch fermentation in the rumen is reduced, which may also reduce the risk of acidosis, and secondly, starch digestion in the small intestine is increased. The latter reduces the degree of starch breakdown in the large intestine, which is more favourable for slowly degradable grains such as maize. Key to the above conclusion is the particle size of micronized grains entering the rumen as [9] found that the endosperm protein, which can act as a physical barrier to protect starch granules from microbial attack, does not work when wheat particle size is less than 1 mm.
When introducing micronization into the fodder preparation process it should be taken into account that, unlike granulation technology, the use of micronization followed by conditioning leads to a reduction in bulk density and an increase in transport costs of up to two times that of untreated grain. This problem could be solved by carrying out micronization followed by grain conditioning directly on the farm before or shortly before feeding. This would require the development of a small micronising unit to be incorporated into the feed processing line.

Generally speaking, micronization plant designs can be divided into two types, those using infrared radiation and those using microwave radiation.

Improvement of units for infrared micronization is aimed at ensuring uniformity of heating of treated seeds with the possibility of separation of non-micronized grain and small impurities, negatively affecting the digestibility of feed, reducing energy consumption of the process of treatment of grain and improving the quality of treatment, reduction of burning of grain to the surface by improving the mechanism of vibration transport [14].

Works on improvement of UHF installations for micronization are carried out in a whole complex of directions, creation of a universal installation for continuous in-line and cyclic UHF treatment of forages, providing adjustment of exposition of processed raw materials, reduction of energy consumption at a given quality of treatment of mixed fodder, combination of UHF exposure with steaming of grain, leveling of nonuniformity of UHF exposure [15].

4 Conclusion

In general, the research on micronization of grain material can be divided into several aspects. The first is the improvement of the micronization process itself, which consists in reducing the energy intensity of the process. In this regard, the use of gas in micronizators seems promising. In particular, it is possible to use generator gas, which is obtained practically from waste products of the same animals and, for example, waste products of grain sorting stations, thereby making the energy source extremely cheap [16]. Secondly, the research on the development and design of technological lines of fodder preparation, which include a micronizer, is promising. These lines can be both stationary, used on large dairy farms, and mobile to provide fodder to a network of small farms. Thirdly, the research aimed at studying the changes occurring in grain as a result of exposure to infrared radiation. This is the most extensive and knowledge-intensive component of micronization research. And, as it is not difficult to notice, the results can vary depending on the variety of grain, its humidity and conditions, which once again emphasizes the relevance of micronization research. And the fourth focus of the study can be given to improving the design micronizer in terms of ensuring the uniformity of treatment of grain and fire safety of the process.

Thus, the research of micronization process has scientific and practical value, thus it is necessary to consider that micronization application will be successful if improvement of productivity and health of animals will exceed the basic expenses on preparation of forages.

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References


