Feed grain micronising plant

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Abstract. The heating process of micronisation plays a paramount role in reducing the amount of anti-pittaels in the feed grain, changing the grain structure and increasing the availability of nutrients and improving their digestibility. The efficiency of heating generally depends on the design solutions used in the micronizing plant. This article gives an overview of some designs of installations for forage grain micronisation and presents the design of an installation for infrared micronisation of forage grain, which makes it possible to increase the efficiency of treatment, by reducing the burning of grain to the surface and ensuring uniformity of treatment.
Keywords: fodder preparation, feed grain, micronisation, processing efficiency, vibration, vibration transport

1 Introduction

Dairy farming productivity depends primarily on the availability of grain, and traditional methods of feed preparation, which consist of simply grinding feed grain, do not allow the energy contained in the grain to be fully extracted [1, 2]. Considering the fact that due to biological characteristics of ruminants the amount of grain forage in the diet is limited, it is relevant to increase the availability of the energy component of grain used in feeding.

One of the widely known ways of increasing the digestibility and energy availability of grains is their preliminary intensive heat treatment using infrared radiation, micronisation. Micronisation of forage allows starch fibres to be destroyed at the molecular level, increasing energy availability, while ensuring the partial physical destruction of the grain structure, which has a positive effect on the energy efficiency of their further processing, crushing or milling.

The efficiency of heating generally depends on the design of the micronisation plant. Generally speaking, micronisation plants can be divided into several groups. In the first group are those used in laboratory research to study in depth the effects of micronisation on the transformation of grains. These plants are characterised by their simple construction and minimal adjustments. The second group consists of units used on an industrial scale, enabling the treatment of different volumes of grain material and featuring a wide range of adjustments. In between the laboratory and industrial applications, the intermediate group is comprised of experimental prototypes. The aim of this group is to experiment with promising designs to increase the efficiency of the micronisation process.

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2 Laboratory micronisation plants

Technological improvement of analysis methods of processes occurring in grain during micronization, such as improvement of microscopy and equipment used in microscopy, and other processes related to laboratory research, make the use of laboratory installations relevant.

The simplest laboratory apparatus (Fig. 1) usually consists of a surface on which a thin layer of grain and an infra-red radiation source are placed [3].

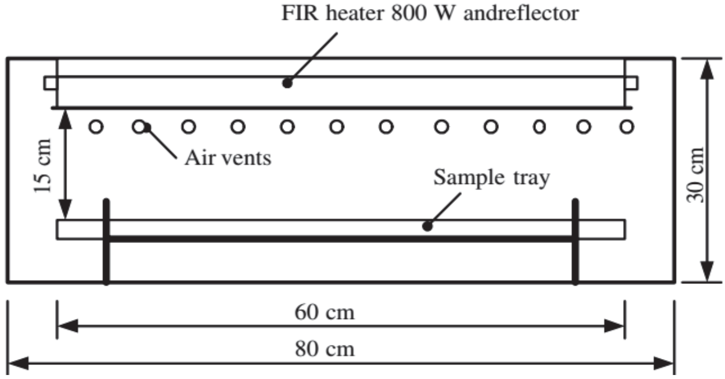

Fig. 1. Schematic diagram of a single layer infra-red dryer. Source: [3].

The distinctive feature of such a machine is its versatility and the possibility of using it not only directly for drying, but also for micronisation research. It should be noted, however, that micronization requires a more powerful infrared radiation source to provide micronization duration in the range from 30 to 90 seconds [4]; moreover, it would be reasonable to add a possibility to change the angle of the infrared radiation source relative to the treated grain layer.

These disadvantages are realised in the following technical solution of a laboratory installation for single-layer micronisation (Fig. 2).

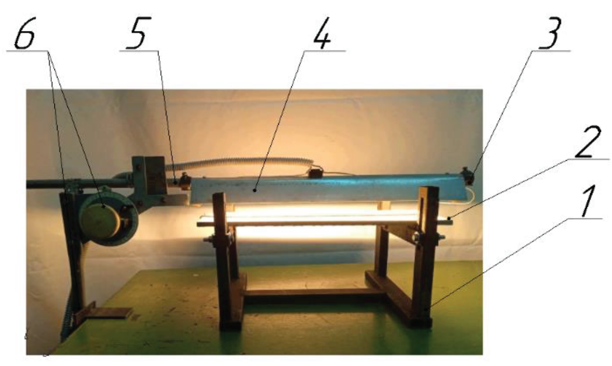

Fig. 2. Laboratory setup. Source: Author's study. Where: 1 - frame, 2 - heat-resistant ceramic surface, 3 - infrared emitter, 4 - reflector, 5 - rod, 6 - rotary fixing mechanism.

A ceramic surface 2 is set on the frame 1 covered with heat-resistant enamel. The IR radiation source 3 with a reflector 4, mounted on a rod 5 at the required height above which is mounted by means of a rotating fixing mechanism 6 providing changing the angle of inclination relative to the surface 2, is fixed to the base of the laboratory bench. Adjustment of the infra-red irradiation source position will provide a wider range of the laboratory unit settings.

3 Industrial micronising plants

Both belt conveyors with a continuous or meshed conveying surface as well as vibrating conveyors can be used as conveying media in industrial micronising plants. The main disadvantage of belt conveyors is the relative immobility of grain on the conveying surface, which causes it to stick to the belt. This disadvantage is deprived by vibrating conveyors, where the grain moves on the surface due to its vibrating oscillations. And the most common and classic scheme is that of a micronising plant comprising hopper A (Fig. 3), equipped with a vibrating feeder B Picture 3, which feeds the grain to the vibrating conveyor C, moving along which the grains come under the influence of the source of infrared radiation E. After infrared treatment, the grain enters the hopper storage F for further processing, it can be, for example, milled or subjected to conditioning. Electrical infrared emitters are used as the source of radiation.

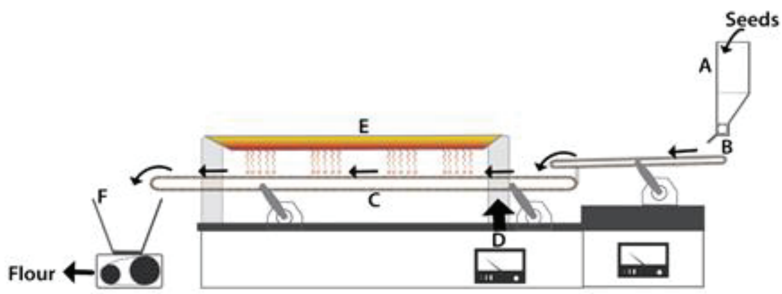

Fig. 3. Classic micronisation plant diagram. Source: [5].

A - hopper, B - vibrating feeder, C - vibrating conveyor, E - infrared source, F - storage hopper, D - power source for infrared emitters

However, the supply of a large amount of electricity is not feasible with a large industrial scale of micronisation. For this reason, gaseous fuel is used as a source of heat and infra-red radiation [6]. The fuel is used to heat the surface of a flameless gas burner (Figure 4, Figure 5) which, when heated, emits infra-red radiation.

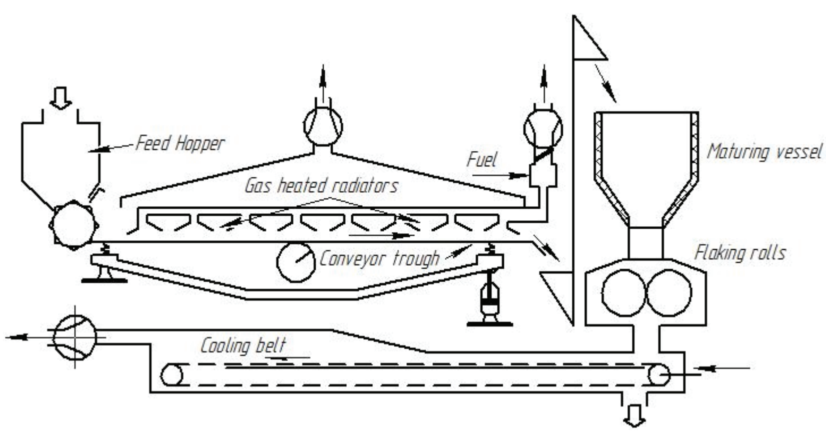

Fig. 4. Industrial micronising plant. Source: [3].

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The use of a particular type of heat transfer medium is primarily determined by economic feasibility. The cost of the pre-processing effort for the grain should at least not exceed the cumulative positive effect of micronisation. For example, if the cost of electricity or natural gas is high in a particular region, generator gas can be used as fuel [7]. Generator gas production can be organized in terms of agricultural production using, for example, waste products of animals and various wastes: grain sorting waste, sawdust, etc.

The main disadvantage of micronisation plants using flammable gas is their fire and explosion hazard. In order to eliminate this disadvantage, efforts are being made to use electromagnetic field energy of ultrahigh frequency (UHF). The advantage of UHF exposure is a high processing speed, penetration depth, inertia-free process. A distinctive feature of microwave units is their versatility, so depending on the settings of microwave radiation intensity, the units can be used in a wide range of functions from presowing microwave treatment of material [8] to increase the seed quality of seeds, to directly in micronization as one of the elements in the technological lines for the preparation of feed [9].

However, the main disadvantage holding back the widespread use of micronization units is the excessive energy intensity of the process, and as noted earlier, the use of such a treatment method must be economically justified.

Nevertheless, infrared micronisation is preferable from the energy point of view and the most frequent method. A great deal of research is being carried out to improve the micronisation process. In a number of researches, scientists use change of the angle of inclination of the vibrating surface in order to extend the range of adjustment of the conveying speed and, accordingly, the processing time [10].

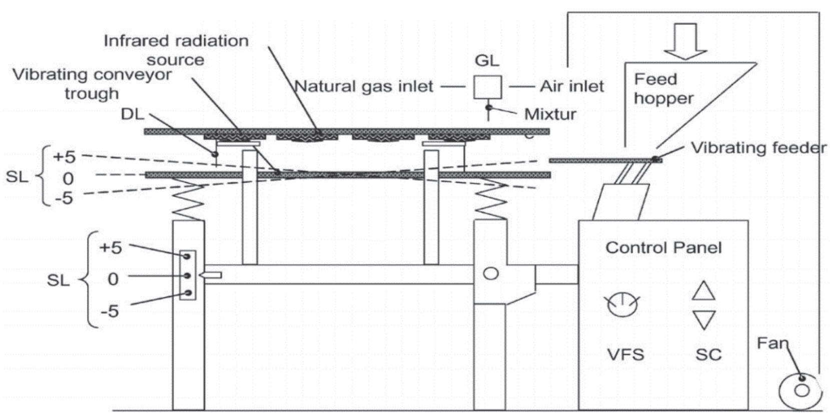

Fig. 5. Changing the inclination angle of the vibrating surface during micronisation. Source: [10].

However, despite the seemingly obvious positive effect of widening the adjustment range (Fig. 5) a negative phenomenon (Fig. 6) can be observed when tilting the vibrating surface, consisting of a displacement of the moving grain from the centre to the periphery of the conveying surface [11, 12]

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Fig. 6. Grain displacement towards the periphery on an inclined vibrating surface. Source: [Author's study].

It can clearly be seen that after hitting the vibrating inclined surface, the grain material gradually begins to shift towards the periphery, forming a gap in the centre of the vibrating conveyor. As a result of this phenomenon the efficiency of micronisation will be reduced.

The negative phenomenon of grain shifting to the periphery when the vibrating surface is tilted can be eliminated by changing the curvature of the conveying surface. Namely, the conveying surface should be concave. Such a solution will not only avoid the displacement of grain to the periphery, but also improve the uniformity of grain handling, due to a kind of mixing of grains in the vibe-fluidised layer. This solution has been realised in the laboratory prototype of the micronisation machine (Fig. 7).

4 Prototype micronisation plant

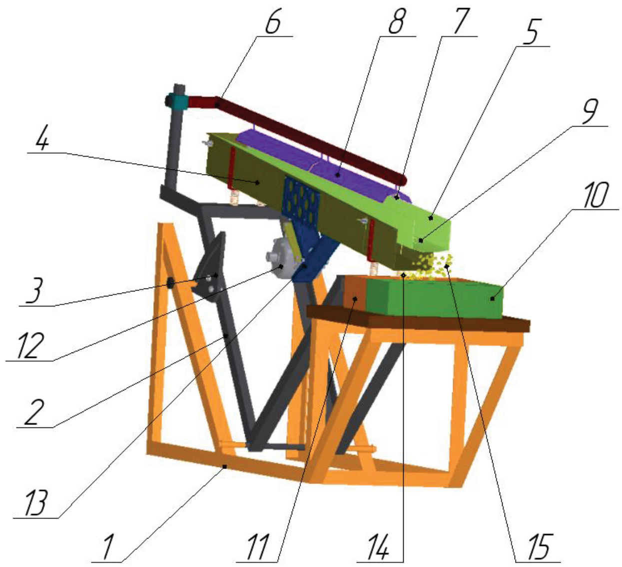

Fig. 7. Prototype micronisation plant.

The unit contains a stationary frame 1 and a rotary frame 2, the position of the rotary frame is fixed by a mechanism 3, a continuous flat-bottomed trough 4 is installed on the rotary frame on a spring hanger, inside of which a trough 5 with a concave surface is located. Infra-red emitters 7 with reflectors 8 are installed above the trough 5 on the rod 6. At the end of the trough there are storage hoppers for micronized grains 10 and for fine impurities 11. The vibration is created by an electric motor 12 with eccentrics on its shaft. The position of the motor 12 is changed in relation to the trough 4 by the mechanism 13 depending on the required vibration characteristics.

The machine works as follows: Grains falling on the vibrating surface of the concave trough 5 are moving along it being exposed to infrared irradiation of the source 7, the movement of grain on the vibrating surface is partial exfoliation of small impurities which at the end of the trough 5 fall through the holes 9 and hit the surface of a flat trough 4, moving on which go into the hopper storage for impurities 11, grain micronized fall into the hopper storage for micronized grains 10. Thus, the use and implementation of this unit for micronization will improve the efficiency of the process.

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