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DEPARTMENT
OF FOOD PROCESS ENGINEERING

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Opinion

concerning the innovativeness and feasibility of implementing modern feed production methods based on micronization technology, as well as plans to launch the production of comprehensive technological lines incorporating micronizers by the company *Mikronizacja Polska Sp. z o.o.*

The Opinion was prepared at the request of Mikronizacja Polska Sp. z o.o., a company based in Żnin, Poland (ul. Szpitalna 20, 88-400 Żnin).

To accurately assess the Nawrocki company's production and investment plans, it is helpful to begin with a concise introduction to micronization technology. This will provide context for the detailed issues explored in the substantive part of the assessment and familiarize readers with the terminology and specialist language used in this relatively new branch of agri-food processing.

Micronization

The micronization process involves the thermal treatment of plant raw materials using infrared radiation. In recent years, it has gained increasing popularity among producers in the agri-food sector. Its most promising applications have emerged in the feed industry, particularly in the refinement of raw materials and the production of specialized, complete feed mixtures. The technology has also been in use in Poland for the past two years.

Feed producers are well aware that increasing the digestibility, assimilability, and safety of feed materials requires the application of various processing methods. In addition to cleaning, dehulling, grinding, conditioning, and pelleting, additional hydrothermal processing is increasingly being applied [4, 7]. An interesting alternative is micronization, which can be successfully employed for the refinement of cereal grains, legumes, and oilseeds intended for feed purposes. This method was pioneered by the English company *Micronizing* in the 1970s, introduced into practice, and rapidly received broad recognition. For many years, leading producers of feed mixtures for highly demanding animals have successfully applied micronization, a process that lowers water activity, improves nutrient digestibility, inactivates anti-nutritional factors, and enhances the hygienic safety of mixtures through sterilization. Until recently, micronization received little attention in Poland, despite its growing circle of supporters worldwide. This situation has gradually begun to change, driven in part by the popularization of research conducted by scientists at the University of Life Sciences in

Lublin [1, 2, 6, 8]. The first plant for producing feed components – equipped with high-capacity micronization lines – has already been established [9].

Given the above context, it is appropriate to present a brief overview of the micronization process. As already mentioned, micronization is a form of thermal processing applied to food and feed raw materials. It involves subjecting whole, dehulled, or ground cereal grains, oilseeds, oilseed meals, and other feed materials to infrared radiation with a wavelength of 1.8–3.4 μm for a relatively short duration, resulting in significant changes to the physical and chemical properties of the processed materials [5, 7]. Infrared radiation excites the molecules of the material, inducing intense vibrations that generate friction, a rapid rise in temperature, and increased vapor pressure within the particles being processed. Water vapor within the material is generated by rapid heating. The temperature of the processed material rises to about 90°C within 50 seconds and, after 90 seconds, reaches 110–130°C or higher (with prolonged exposure to radiation, up to 230–250°C). Such high temperatures are applied only briefly – typically for 45–90 seconds, depending on the material type. For example, cereal grains are exposed to radiation for about 50 seconds, which is sufficient to induce starch gelatinization in the kernels. After leaving the micronizer, the material undergoes cooling and, very often, flaking (crushing).

Micronization is classified as a high-temperature, short-time (HTST) process, in which plant-based material is rapidly heated to approximately 130°C for several tens of seconds before being cooled.

A standard micronization line consists of several basic components, including a feed conveyor, a feed hopper, a belt conveyor that carries the material through the heating zone, infrared emitters, and equipment for cooling, grinding, and transporting the product to packaging or subsequent stages of production.

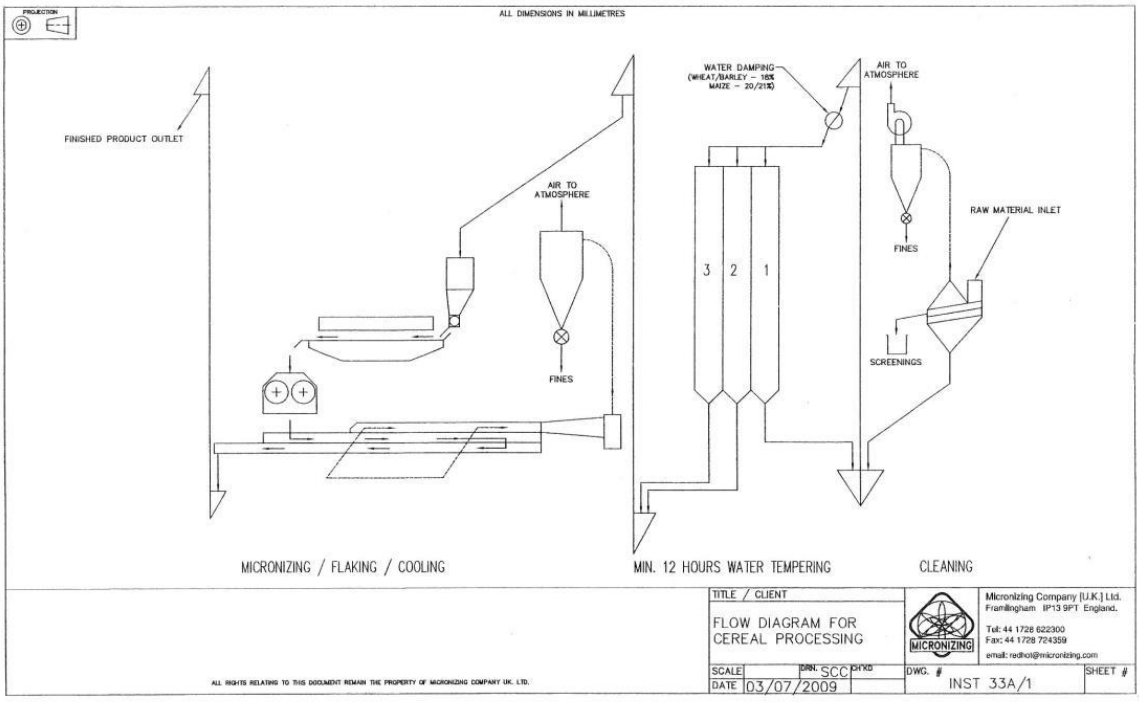

Fig. 1. Diagram of a micronization process line [10].

Before being introduced into the micronizer, the material must be thoroughly cleaned and moistened to a moisture content of 17–20%. It is then transported to the dosing and thermal treatment section, where it is exposed to infrared radiation for 45–90 seconds. After leaving the micronizer, the hot material enters a cooler for rapid cooling, before typically passing through the crushing rollers and continuing onto the production line.

A micronization line typically incorporates a range of highly advanced technical machines and equipment. The source of infrared radiation may be either electric infrared emitters or gas-fired ceramic emitters. In electric emitters, radiant energy is produced by the heat generated in the heating element as electric current flows through it. The main components of gas-fired emitters are ceramic plates equipped with fine perforations. A mixture of gas and air is supplied to the plates; after passing through the perforations, the mixture undergoes combustion, which raises the surface temperature of the plate to 850–900°C and causes it to emit infrared radiation.

Among electric emitters, the most common are lamp-type emitters with tungsten filaments and reflectors, which convert up to 65% of the input power into infrared radiation. Also used are quartz emitters with tungsten filaments and halogen lamps. In general, emitters can be divided [7]:

- by shape: into point, linear, and planar;
- by spectral range and filament temperature:
into those emitting dark radiation (filament temperature does not exceed 1000°C) and bright radiation (filament temperature exceeds 1000°C);
- by method of radiation generation: into thermal, luminescent, and laser;
- by spectral characteristics: into non-selective and selective.

In the feed industry, the use of micronization is justified in the production of specialized mixes, including prestarters, dietary and high-energy mixtures, and so-called musli mixes. It can be successfully applied in the processing of full-fat oilseeds, mainly soybeans. Its use is also economically justified for reducing the content of anti-nutritional substances and as a preventive measure against the development of fungi and molds in all types of feed materials. All these findings are confirmed by scientific studies [5, 7, 8, 9, 10].

Photo 1. Examples of micronized products [9].

Changes in the physicochemical properties of raw materials subjected to the micronization process

The interaction of infrared radiation, which causes an increase in temperature and water vapor pressure inside kernels, induces the following changes [1, 2, 5, 8]:

- reduction in the strength of the seed coat due to the rupture of cell membranes,
- complete gelatinization of starch,
- destruction of anti-nutritional components,
- improved digestibility of starch and protein,
- denaturation and inactivation of enzymes: urease, lipase, amylase, and trypsin inhibitor,
- increased shelf-life of feed materials,
- sterilization (destruction of bacteria, viruses, molds, and yeasts).

The extent of these changes depends on the properties of the feed material being processed, as well as the duration and parameters of the treatment. All these features contribute to improved safety and hygienic quality of feed materials, enhanced palatability and increased feed intake, greater digestibility of feed materials, and consequently to a faster growth rate and better feed utilization by animals.

Studies show that micronized feed materials have a higher metabolizable energy content compared with untreated materials (see Table 1).

Table 1. Change in the metabolizable energy level of cereals [MJ] due to the micronization process [8].

Type of feed material	Unprocessed grain	Micronized grain
Wheat	12.9	14.4
Barley	11.5	13.7
Maize	14.3	15.75

The energy value of a feed mixture is the most cost-intensive nutritional parameter, influenced primarily by the levels of available carbohydrates − mainly starch − and fats derived from the constituent raw materials. Cereals play a pivotal role in balancing the diets of farm animals. They provide a substantial amount of minerals and valuable energy in the form of starch. However, it is worth noting that the starch present in raw, untreated cereals is largely unavailable and poorly digestible – especially for young animals whose digestive tract is not yet fully developed and whose enzymatic system is still maturing. Prestarter-type mixes, despite their high content of animal-derived products, also contain cereals, full-fat legume seeds, and oilseed meals, which include starch in their composition. Subjecting these components to the micronization process causes starch gelatinization, i.e., the breakdown of its particles by disrupting the starch granule structure and opening the molecular chains, which were previously tightly packed into a complex structure with many branches. Infrared radiation causes starch to soften, swell, rupture, and gelatinize. This transformation enables the breakdown of starch particles into simple sugars and disaccharides, making them more accessible and significantly easier to digest for young animals. As a result, the feed material demonstrates enhanced palatability, increased intake, and significantly improved digestibility and nutrient absorption.

Table 2. Change in the digestibility of starch in cereals [%] due to the micronization process [9].

Material type	Starch digestibility in unprocessed material	Starch digestibility in micronized material
Barley	35	98
Wheat	28	90
Maize	43	92

Table 3 presents the results of chemical analysis of micronized soybean, rapeseed, corn, wheat, and barley grains. The listed values of amino acids and essential nutrients in the processed raw materials confirm the general consensus regarding the beneficial changes that occur during micronization.

Table 4, in turn, presents data, also derived from the literature, on the effect of micronization on the microbiological purity of wheat, rye, and barley, including both grains and flakes. They provide clear evidence of satisfactory hygienization effects in the processed components.

Table 3. Results of the chemical analysis of selected micronized products [5, 10].

TYPICAL ANALYTICAL VALUES OF MICRONIZED PRODUCTS

	SOYA BEAN	RAPE SEED	MAIZE	WHEAT	BARLEY
PROTEIN	39.00	21.00	9.50	11.00	10.00
OIL	19.50	44.00	3.80	1.90	1.70
FIBRE	5.00	6.70	1.70	2.50	4.50
LYSINE	2.50	1.20	0.28	0.35	0.37
METHIONINE	0.55	0.47	0.19	0.19	0.17
M + C	1.04	0.79	0.37	0.40	0.40
TRYPTOPHAN	0.60	0.27	0.09	0.10	0.15
THREONINE	1.56	0.85	0.39	0.31	0.34
ARGININE	2.80	1.20	0.45	0.47	0.60
DE PIGS (mj/kg)	19.30	26.00	16.56	16.10	14.19
ME RUM (mj/kg DM)	17.00	20.80	15.53	15.18	13.75
ME POULT (mj/kg)	15.69	20.50	15.87	14.72	13.09
CALCIUM	0.24	0.47	0.02	0.04	0.07
PHOSPHOROUS	0.50	0.56	0.32	0.30	0.42
AV. PHOSPHOROUS	0.17	0.17	0.10	0.09	0.13
SALT	0.07	0.08	0.08	0.13	0.12
LINOLEIC ACID	9.50	10.10	1.90	0.95	0.85
DRY MATTER	90.00	92.00	86.00	87.00	86.00

PLEASE KEEP IN MIND THE ANALYTICAL VALUES FOR THE RAW MATERIALS WILL VARY SLIGHTLY FROM COUNTRY TO COUNTRY DEPENDING ON GROWING CONDITIONS I.E. SOIL VARIATIONS, WEATHER, HARVEST CONDITIONS AND METHODS OF DRYING WET GRAIN (WHICH IS SOMETIMES DRIED WITH DRYING TEMPERATURES FAR TOO HIGH, THUS TENDING TO DENATURE THE BIOLOGICAL VALUE OF THE GRAIN IN THE MONOGASTRIC ANIMAL).

METABOLIZED FIGURES ARE QUOTED AS MEGAJOULES. TO CONVERT TO KILO/CALORIES:

DIVIDE MEGAJOULES BY 4.184 AND MULTIPLY BY 1,000, I.E. D.E. FOR MICRONIZED SOYA DECLARED AS 19.300 MEGAJOULES

19.30 ÷ 4.184 x 1000
= 4.613 x 1000
= 4613 K/CALS

OR M.E. POULT 15.69 MEGAJOULES ÷ 4.184 x 1000
= 3750 K/CALS

Table 4. Microbiological characteristics of selected micronized cereal products [5, 10].

MICROBIOLOGICAL SPECIFICATION
Post infra red Micronizer processing

PRODUCT TORREFIED WHEAT, RYE AND BARLEY
FLAKED WHEAT, RYE AND BARLEY

	MIN	MAX
STANDARD PLATE COUNT AT 30 °C/g	1×10^3	1×10^4
MESOPHILIC SPORES /g	1×10^2	1×10^3
YEAST AND MOULDS /g	1×10^2	1×10^3
SALMONELLA /g	NOT FOUND	
STAPHYLOCOCCUS AUREUS /g	NOT FOUND	
CLOSTRIDIUM PERFINGENS /g	NOT FOUND	
E. COLI TYPE 1 /g	NOT FOUND	

skh 1.8.90

Micronization also increases the amount and availability of fat, since the high temperature in the processed feed material inactivates lipases and lipoxygenases, i.e. the enzymes responsible for the breakdown of lipids.

In feed materials subjected to micronization, the total protein content generally remains unchanged. However, as with most thermal processing techniques, the proportion of digestible protein – i.e., the fraction that can be absorbed and used to meet the animal's nutritional requirements – tends to increase. In general, micronization can increase the level of digestible protein in feed materials by up to approximately 10%. In components with a high total protein content, the improvement may be even greater. This rise in digestibility is attributed to the effects of high temperature, which disrupts double bonds between amino acids while preserving the internal bonds within amino acid molecules. As a result, the protein structure breaks down without compromising the integrity of the amino acids themselves. The quality of micronized products is significantly influenced by the efficiency and quality of the micronizer, as well as the operator's experience in controlling the process. The high temperature of micronization additionally contributes to the protein denaturation effect, which is particularly useful in processing oilseed seeds, their cakes, and post-extraction meals, and enhances the digestibility of nutrients.

High temperatures also deactivate enzymes and a significant amount of anti-nutritional substances. The enzyme urease, present in large quantities in soybeans, loses its activity under the high temperature occurring during the micronization process and breaks down into urea and ammonia. The same occurs with trypsin inhibitors – anti-nutritional proteins found in soybeans. Their removal results in higher trypsin activity, which hydrolyzes protein molecules, thereby increasing the potential for protein utilization in animal feed. The micronization process itself causes seeds – especially soybeans – to develop a

characteristic ‘nutty flavor,’ which makes them more readily consumed by animals. Feeding animals with raw soybean meal leads to increased chick mortality and significant loss of efficiency due to changes in feed conversion ratios across all species. Older animals can partially compensate through increased pancreatic activity, but they do not regain lost performance.

The use of micronized full-fat soy provides tangible benefits in broiler farming throughout the entire fattening cycle, as this component contains 20% oil and has an AME (apparent metabolizable energy) value of 17.6 MJ/kg. In turkey and laying hen production, the inclusion of this component is particularly important due to its high content of omega-6 fatty acids. Micronized full-fat soy is also widely used in piglet diets because of its high nutrient content, palatability, and aroma.

Nutrition

Micronization offers a key advantage by enabling the controlled gelatinization of starch across a diverse range of grains, which enhances nutrient absorption and significantly improves feeding efficiency in livestock. EU directives stress the need for proper piglet nutrition and set strict standards to ensure compliance. Since herd performance has improved due to higher sow productivity, ensuring efficient nutrition of young pigs is particularly important because of their earlier weaning. Piglets weaned at 3–4 weeks of age are dependent on lactose from sow’s milk. Switching them to a starch-based diet would require a longer time, as the activity of amylase in their digestive tract is not yet fully developed. Unprocessed or insufficiently gelatinized starch can pass to the hindgut with potentially fatal consequences. Introducing micronized feed into the diet acts as an antidote in this case; moreover, it shortens the fattening cycle, which impacts overall feed consumption and the total cost of rearing [5, 7, 9, 10].

In the United Kingdom, it is estimated that over 80% of piglets are fed diets incorporating micronized wheat and corn, primarily due to the enhanced starch gelatinization achieved through this process [5, 10]. However, it is important to note that micronization may also lead to the excessive formation of Maillard reaction products, which can result in the development of indigestible amino acid complexes. Although this is a THST process and can be controlled through the selection of processing parameters, UK breeders generally include micronized cereals in piglet diets at levels of up to 60% (of which up to 15% may be micronized full-fat soy).

In modern production systems for dairy calves, solid feeds – such as fresh forage, silage, hay, and concentrated mixtures – are offered *ad libitum* from as early as the second week of life. These feeds are essential for the proper development of the digestive tract, particularly the forestomachs. The physical form of the feed ration has a fundamental impact on the structure and shape of the mucosa in the forestomachs and small intestine, daily weight gains, and subsequent feed utilization. Feeds with a high starch content have the greatest influence on the rapid development of the reticulum, rumen, and omasum. For these reasons, in some calf management systems it is recommended to offer ad libitum a complete starter concentrate containing micronized ingredients from the 4^{th}–6^{th} day of life [5].

Feeds produced in the EU for racehorses and “recreational” horses contain up to 30% cereal muesli-type micronized ingredients (enriched with molasses, coarsely ground mix of cereal

flakes, beans, peas, and legume and oilseed seeds). In addition to their visual appeal for owners, their primary advantage is that horses in stables consume such feed much more slowly [10]. Pet foods available in stores for small mammals (rabbits, guinea pigs, mice, and many other pets) also contain a significant proportion of micronized cereal components.

Micronization can be successfully applied in the production of certified feeds and feed components, i.e., those made from non-GMO raw materials and sourced from organic farming. This specialized production sector is gaining increasing market significance, with its outputs classified as so-called dedicated products, which directly contributes to the increased profitability of their manufacture.

Micronization is also increasingly being applied to the processing of gluten-free cereals – an area that has seen rising consumer interest in recent years. **Gluten-free diet** was undeniably one of the most prominent dietary trends in 2016. Until recently, its use was limited solely to individuals with celiac disease or wheat allergy as a necessary therapeutic measure. Today, beyond medical reasons, an increasingly common motivation for excluding gluten from the diet is the desire to lose excess weight or simply to follow the widespread gluten-free trend.

Statistics clearly show that a growing number of people are adopting gluten-free diets. **Safe, naturally gluten-free foods include** rice, corn, buckwheat, millet, amaranth, sorghum, teff, tapioca, and quinoa. This category also includes many legumes, seeds, nuts, fruits, and vegetables. Thus, the various types of flakes mentioned above – including those made from micronized legumes – can be successfully marketed as gluten-free products. The presence of the licensed Crossed Grain symbol on packaging − subject to formal authorization − reassures consumers that the manufacturer adheres to strict procedures to prevent contamination at every stage of production. Most importantly, it certifies that the products undergo regular, verified testing.

Costs

The implementation of micronization technology entails additional costs, prompting feed producers to carefully evaluate its economic viability. At our request, the British company *Micronizer* – a leading manufacturer of technological lines – prepared an estimate of the investment and operating costs for implementing a cereal micronization line with a capacity of 5–6 t/h for corn and wheat flakes under Polish conditions (see the calculations below) [5].

MICRONIZER LINE EURO OPERATING COSTS MAY 2016
POLAND

including : Infra Red Micronizer M600/90/HRS
600 dia x 1300 Flaking Mill
VK24 Vertical Cooler (local supply)
V10 Vibronet water pre-treatment control

Investment:		Budget Euro 500.000,-			
Capacity:		6,0 tonnes/hr Wheat Flakes (5,0 tph Maize Flakes)			
Annual Production (300 days):	(1)	8 hours per diem =	14.400 tonnes per annum		
	(2)	16 hours per diem =	28.800 tonnes per annum		
Current Av. Electricity Costs		Euro 0,09 per kW (Av day/night tariff)			
Current Av Natural Gas Costs		Euro ? per m3 /hr			
Current Av LPG Propane Gas Costs		Euro 0,27 per litre			
Micronizer 'On Cost' Per Tonne		**Euro**	**(1)**	**Euro**	**(2)**
Energy					
(Total connected electricity 114 kW)					
Electrical load 80 kW/hr		1,20		1,20	
= 70% consumption.					
LPG Propane 98 litres/hr		4,41		4,41	
(alternatively Nat. Gas 62 m3/hr)					
(infra red energy source)					
Cleaning losses (maize)					
As per extrusion/pelleting process		0,00		0,00	
Maintenance					
Euro 4.800,- per annum			0,33		0,17
Total 'On Cost' per Tonne			**5.94**		**5.78**
+ Depreciation over 5 years					
20% per annum (Euro 500.000,-)		6,94		3,47	
+ Cost of interest on investment					
10% per annum (Euro 500.000,-)		3,47		1,74	
Total per tonne including financing			**16.35**		**10.99**

The presented data indicate relatively low operating costs, which will be fully offset by the higher quality of the final product, justifying the producer's demand for higher prices. The cost of purchasing a process line with the mentioned capacity also raises no concerns when compared to other installations used in thermal processing of plant materials.

Investment and production plans of Mikronizacja Polska Sp. z o.o.

The drive to improve production performance in livestock farming has led feed manufacturers to adopt increasingly advanced processing techniques, aimed at enhancing the digestibility and bioavailability of feed materials for animals. Micronization is not an inexpensive process, yet it is undeniably effective. The use of micronized components has a positive effect on animal health and production parameters in pig farming (particularly in piglets) as well as in poultry and calf rearing. The technology has been successfully employed for several years in Western Europe and, more recently, in Poland. Micronized products have a significantly higher nutritional value, digestibility, and are much more palatable than ordinary meals. They are also microbiologically pure, and therefore safe to use, which plays a significant role especially in the feeding of young animals and sows. The micronization technique was practically implemented in Poland two years ago, when the company *Michel – Pasze Sp z o.o.* built the only medium-sized plant for micronized feed to date, located in Śmigiel. Several trading companies offer imported micronized feeds and feed components on the Polish market, but their sales remain relatively low due to the comparatively high price. As interest in micronized feed continues to rise, Poland is expected to experience a corresponding increase in demand, consistent with patterns seen across Western Europe. The number of pig and poultry breeders recognizing the benefits of

micronization and incorporating its products into animal feed is steadily growing. This trend highlights a genuine need to scale up domestic production (both in terms of equipment and product variety), which would not only boost supply but, more importantly, contribute to lowering product prices.

Mikronizacja Polska Sp. z o.o. aims to enter the market by offering production lines equipped with micronization technology. These lines will be available either as independent, stand-alone units or in partnership with Nawrocki Sp. z o.o. – a supplier of comprehensive industrial feed plants, which will be additionally enhanced with micronization capabilities. To support this initiative, the company intends to pursue EU funding through the submission of targeted grant applications.

The Applicant anticipates delivering these production lines in three distinct sizes, tailored to varying operational needs:

- small-scale projects: lines with a capacity of 1.5 – 2.0 t/h;
- medium-scale projects: lines with a capacity of 3.0 – 4.0 t/h;
- large-scale projects: lines with a capacity of 6.0 – 7.0 t/h.

The production and supply of complete production lines for feed and feed components will be carried out in close cooperation with the British company *Micronizing Company UK Ltd*., which will deliver not only the core micronization equipment but also expert support throughout commissioning and operational use.

Given the growing interest in feed micronization in Poland and across this region of Europe, the assumptions adopted by the Applicant can be considered sound, innovative, and economically compelling. Implementing the project's objectives will promote the adoption of micronization technology, particularly among small and medium-sized Polish feed producers. This will contribute to expanding the range of specialized, safe, and high-value feed components they offer. Supplying individual or complete production lines through an experienced domestic feed manufacturer will help reduce investment, servicing, and related costs, while also supporting increased employment at the production site.

In conclusion, given the predominantly positive aspects of micronization technology, its significant contribution to enhancing the quality of feed raw materials, and the limited domestic availability, I firmly believe the submitted project merits a clearly favorable evaluation.

I consider the Applicant's objectives and their execution to be both innovative and economically viable, particularly within the context of the Polish national market. There are credible grounds to anticipate that, due to the efficiency of the offered facilities, they will attract the interest of SMEs, specifically feed producers in neighboring countries. In my opinion, the Applicant has a justified basis for seeking financial support from EU aid funds.

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