

Project “Competitive Farm” under the Lithuanian Rural Development Programme 2014–2020 Measure “Cooperation”, Activity Area “Support for the Establishment and Operation of EIP Operational Groups”

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PRODUCTION OF GREEN FEED USING HYDROPONIC TECHNOLOGY OF VERTICAL AGRICULTURE, RATION FORMULATION AND CATTLE FEEDING ON DAIRY AND BEEF FARMS



Picture 1. Feed grown on the training farm of VMU Agriculture Academy

Authors: **Vigilijus Jukna,**
Živilė Tarasevičienė,
Astrida Miceikienė,
Antanas Maziliauskas,
Rolandas Bleizgys,
Vytautas Magnus University

SUMMARY

Between 2016 and 2019, the researchers of Vytautas Magnus University, advisers of the Lithuanian Agricultural Advisory Service together with farmers and their associations implemented the European Innovation Partnership project “Competitive Farm”, which tested and adapted the innovation of cattle feed production and feeding using hydroponic technology.

Population growth, increased demand for food, problems related to ensuring food availability, climate change, and rational use of natural resources are forcing us to make new decisions regarding the development and use of new technologies, techniques, and measures.

Germination of seeds for food is a well-known method, leading to changes in chemical composition, while germination of grain seeds for feed production was introduced even earlier. The project used grain germination using hydroponics that is a widely used method of soil-free cultivation in greenhouses with dosing either water or water with nutrient solutions as appropriate. The hydroponic system is installed in a room with controlled air temperature, humidity, and lighting with seed preparation equipment and five- to six-story shelving units arranged vertically for germination with an automated system for irrigation, dosing, and water collection. Sprouted grains, evenly distributed on the shelves, produce shoots within 7 days, which are then used to feed animals by mixing them with the conventional feed.

The main advantages of this feed production method are that no soil is needed, and little water is required to grow the feed. The short feed production cycle allows for quick and flexible adaptation of feed production to changing needs.

Successful feed production depends on the quality of germinated seeds, hygiene, and conditions during the production. The main controlled environmental factors in the feed production are air temperature, relative humidity and watering of germinating seeds. Depending on the germination conditions and the seed type, the weight can increase from 2.30 to 8.37 times.

The project idea was to combine innovative feed cultivation, preparation and cattle feeding technologies that use balanced feeds with new products, i.e. natural biologically active plant additives, produced by innovative vertical hydroponic technology based on farmed wheat, barley, maize, peas, soybeans, alfalfa shoots, as well as new target rations with new products, feeding innovations, and organizational tools into a single innovation process. In addition, the project aimed to test, study, and adapt them on dairy and beef farms of various sizes and productivity in different regions of the country. The aim was to balance the productivity of dairy and beef cattle, and to improve the quality of production while reducing production costs compared to current feeding rations and methods, to reduce the use of water and land resources for fodder, to investigate the possibility of reducing methane emissions from cattle due to more efficient decomposition of carbohydrates in the rumen by using biologically active additives, i.e. sprouts.

Six dairy, beef, and mixed-type farms of different sizes and enterprises (see Table 1) from different geographical regions of the country (Samogitia, Aukštaitija, Central Lithuania, Suvalkija) participated in the project activities. Experimental and control groups of cattle were formed and the research on the efficiency of the applied technology in growing grain sprouts and supplementing rations with them was performed.

According to the research and production results of grain sprouting, the production cost per kilogram varies from €0.06 to €0.12. A major part of the direct costs of growing them on farms consists of seed acquisition costs and staff salaries. The seed costs depend on the sprout type and account for up to 35–45% of the direct costs. The cheapest are barley seeds (0.19 Euro/kg) while the most expensive are alfalfa seeds (up to 4.90 Euro/kg). Therefore, the use of farm-grown grain seeds may lead to lower feed costs. Employees' salaries represent up to 20–30% of the total cost of sprout growing. As for the indirect costs that make up the cost of production, the highest ones are related with heating and microclimate maintenance (14–23%). However, their share in the cost of 1 kg of feed decreases when hydroponic equipment is used more intensely.

Farm	Brief description of activities, experience and resources
Farm A	The main farm activity is the rearing and evaluation of fattening bulls according to fattening and meat characteristics. The company also sells cattle for breeding and meat.
Farm B	The main activity is seed production of cereals and perennial grasses. It is also a breeding cattle and dairy farm. The farm produces about 500 tons of highly –reproductive seeds of grasses and legumes, about 20 tons of perennial grass seeds, 961 tons of milk, and 63 tons of meat.
Farm C	The main farm activity is the production and sale of milk, the cultivation and sale of cereals, oilseed rape, and grain seeds as well as fodder preparation. The farm has about 800 cattle, of which about 350 are dairy cows.
Farm D	The main farm activity is the production and sale of milk, the cultivation and sale of cereals, grain seeds as well as fodder preparation. The farm manages about 1,000 hectares of arable land and currently has about 800 animals of different breeds of, including 450 dairy cows.
E farm	The main farm activity is the production and sale of milk, the cultivation and sale of cereals as well as fodder preparation. The farm has about 80 cattle, including 40 dairy cows, and manages about 52 ha of arable land.
Farm F	The main farm activity is organic beef production, animal breeding and sale, the production and sale of organic cereals as well as fodder preparation. The farm has about 300 ha of arable land and about 200 cattle.

Table 1. Farm characteristics.



Picture 2. Farm D is equipped with a grain-soaking tank.

During the experiments, the addition of germinated grains to rations increased the total cost of production due to the need to produce an additional feed supplement but increased productivity and revenue. In this case, supplementing the rations for the experimental cattle groups with 2 kg of germinated grains, the cost of 1 kg of weight gain increased from 1.4–1.7% (when germinating peas, wheat and barley) to 7.8% (when germinating alfalfa) compared to that of the control group. Similarly, the cost of 1 kg of milk from the experimental cow groups was 2–6% higher than that from the control group of cows. In both cases, however, the economic effect was due to an increase in weight gain or milk productivity. To assess the economic effect, the ratio of the financial result as the difference between the sales revenue and the total costs due to the increase in weight gain or milk productivity and the productivity income from the control group is taken and expressed as a percentage.

Having compared the average weight gains of the fattening cattle from the experimental and control groups, it occurred that the average daily weight gain of the experimental group, whose ration was supplemented with sprouts, was higher, however, it differed significantly from farm to farm and from test to test as well as when applying various grain seeds.

The addition of sprouted grains to the ration of fattening bulls caused a faster weight gain of 9.4–19.3%, resulting in the economic effect of about 8–14%. The mixture of sprouted wheat and barley (50:50) had the greatest influence on the weight gain of bulls. Thus, it is recommended for a wider use. The most significant influence of germinated grains on the weight gain of bulls was before they were 14–15 months old, and the fastest – in the first five months of their lives, when the effect on the weight gain reaches as much as 30.4% when supplementing their ration with a mixture of sprouted wheat and barley (50:50).

Besides the direct economic effect, the addition of sprouts to the feed ration has a positive impact on other important indicators that affect the value of the cattle or meat. Sprouted alfalfa and pea seeds had the greatest influence on meatiness indicators. The bulls fed with them had a higher carcass yield (1.21% and 0.59%, respectively) from the hip-thigh part of the carcass, where the meat is most nutritionally valuable. Moreover, the addition of germinated cereals to the ration of bulls had a positive effect on the fatty acid structure of the meat (the content of unsaturated and harmful fatty acids in the meat of the animals fed with sprouts was 13.78–15.70% or about 1.8 times lower than that of the control group of bulls).

Although the addition of sprouted alfalfa seeds is quite effective in terms of production quality, especially at the end of the fattening period, its use can be expensive due to the high seed price (about 4 Euro/kg), which significantly increases the cost of feed production compared to traditional feed rations (a 7–8% increase) and reduces the economic effect. It is recommended to use peas as an inexpensive seed component when mixing with barley, wheat or a mixture thereof.

Seeds	Vitamin C, mg 100 g-1 GM*	Chlorophyll a, mg 100 g-1 GM*	Chlorophyll b, mg 100 g-1 GM*	Total carotenoids, mg 100 g-1 GM*
Clover	1.75 ± 0,02	10.35 ± 0.80	7.46 ± 1.38	2.95 ± 0.22
Peas	4.00 ± 0,50	23.40 ± 0.70	34.10 ± 1.50	9.80 ± 0.20
Organic wheat	1.76 ± 0.03	20.61 ± 0.28	6.49 ± 0.73	4.73 ± 0.20
Wheat	1.75 ± 0.01	14.03 ± 0.49	9.64 ± 0.67	2.32 ± 0.11
Barley	1.75 ± 0.25	22.50 ± 2.35	14.67 ± 3.59	4.41 ± 0.25
Beans	9.18 ± 0.48	5.79 ± 0.35	6.00 ± 0.58	1.14 ± 0.07
Maize	2.04 ± 0.04	3.35 ± 0.14	1.63 ± 0.16	1.56 ± 0.35
Alfalfa	5.38 ± 0.27	8.61 ± 0.02	12.33 ± 0.16	2.83 ± 0.05
Oats	8.75 ± 0.12	9.50 ± 0.10	16.80 ± 0.41	5.25 ± 0.34

Table 2. Content of biologically active compounds in seeds germinated for seven days (*GM – green matter).

Based on the experience of the project, it is proposed to add 2 kg of germinated wheat and barley mixture (50:50) to the main ration to increase the growth rate of bulls raised for meat before they are 14–15 months old and 2 kg of sprouted peas to improve meatiness and meat quality. To obtain a very high biological and nutritional value of beef, 2 kg of germinated alfalfa seeds (if the need for high quality justifies a relatively high cost) should be added to the main ration every day.

According to practical experience in the use of sprouted grains on US farms, it is possible to gradually increase the proportion of sprouts in the ration of fattening bulls up to 10 kg per day, completely replacing grains or the concentrated feeds. This can reduce the production cost and even obtain up to 20–30% of the direct economic effect.

During the experiments, having compared the increase in milk yield from the experimental and control groups of dairy cows, the average milk yield of the cows, the ration of which was supplemented with 2 kg of sprouts, was 4 to 33% higher but differed significantly from farm to farm and from test to test, as well as when applying various grain seeds. Reliable research data

show that the addition of 2 kg of germinated barley or triticale, a mixture of triticale and barley, a mixture of barley and peas, or sprouted wheat to the ration of dairy cows resulted in an average of 8–17% more milk per month compared to the control group of cows. The estimated economic effect considering the increase in sales revenue and the production cost of additional feed is 6–15%. In individual cases, good results are obtained by supplementing the ration with the addition of bean or oat sprouts, resulting in an additional milk yield of 10 or 17%. However, germination of these seeds is not advisable due to insufficient weight increase of bean sprouts during germination or poor germination of oats.

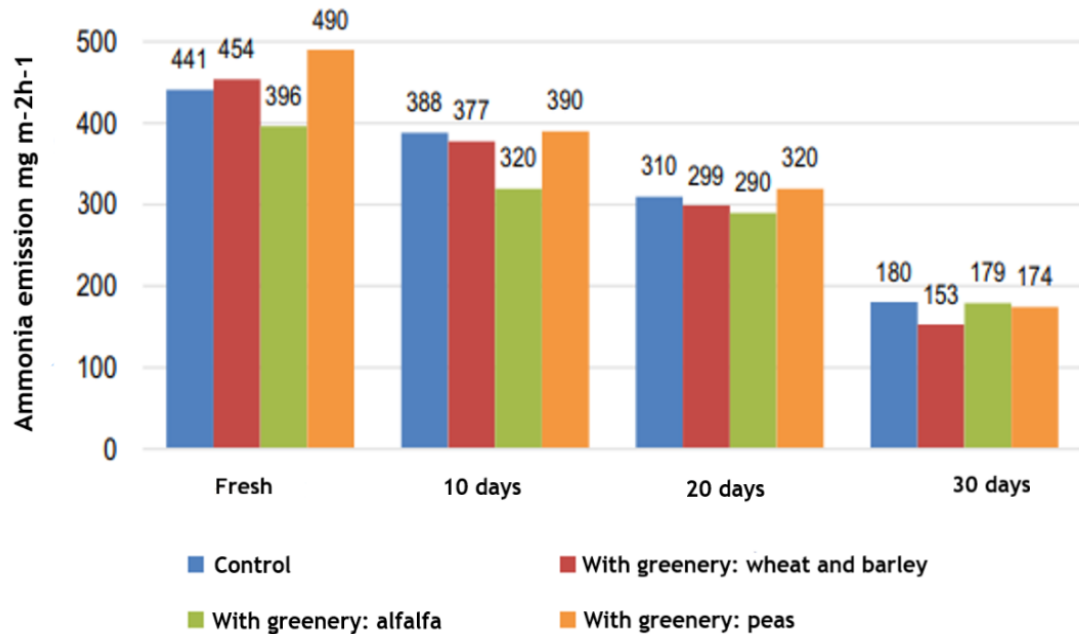
Based on the experience of the project, it is proposed to add 2 kg of sprouted wheat and barley (50:50) mixture or sprouted peas or beans to the main ration to increase the milk yield, milk fat and protein obtained per cow. The use of peas is practically acceptable, but the use of beans is less attractive due to the lower weight of the shoots obtained by germination compared to other grains.

In order to reduce the production cost, a part of the concentrated feed can be replaced with sprouts. According to the project data, replacing 2 kg of the concentrated feed with 4 kg of barley and wheat sprouts, the cost of which per kilogram is at least twice as low, can produce about 8% additional milk yield. Using this ratio of feed adjustment will not change the feed cost, and the resulting additional milk yield will lead to the economic effect of 8%.

Practice and production testing when the concentrated feed was replaced with wheat or barley sprouts at the ratio of 1:1, i.e. 1 kg to 1 kg or 2 kg to 2 kg, allow expecting a reduction of milk production costs by at least a few percentage points while maintaining a similar milk yield. Good quality of sprouts is important.

This change is also beneficial in terms of land use. In other words, the available land is usually used to grow feed grain, thus it can now be used to grow commercial higher value-added food grain. According to the experience of individual farmers, on a large dairy farm this results in an additional economic benefit of up to 3% that can be added to the economic effect of milk production.

Reducing air pollution with ammonia is crucial for the development of sustainable technologies in animal husbandry. Experimental studies showed that the use of sprouts in the rations for cattle does not increase air pollution, but there is a tendency for ammonia emissions to decrease. This positive tendency is due to the more efficient decomposition of carbohydrates in the rumen of cattle using biologically active additives, i.e. sprouts.



Picture 3. Ammonia emission intensity from cattle manure kept at different times (control - cattle fed usual rations; with sprouts - there were sprouts in the cattle ration).

Before deciding to implement these feeding innovations, we suggest taking into account other benefits identified by the farmers involved in the project, which are difficult to assess in terms of the direct economic effect:

- Feed supply is more even, regardless of the season and climatic conditions;
- Balancing feed with rations for highly productive animals is difficult because, for example, increasing the amount of grain alone would not have an effect; The vertical hydroponic system produces fresh, balanced feed that is acceptable and the most beneficial to the animal;•
- Milk quality indicators are noticeably better as there is more protein, fat, lactose while the milk is tastier;
- Health indicators of cattle are noticeably better because sprouts are rich in biologically active phytohormones and various minerals, which are easily absorbed by the animal's body;
- There is a clear improvement in the insemination rates of cows, which brings additional economic benefits as farms usually use expensive and high-quality breeding bull semen produced in the US. Thus, if a farm must inseminate several times, it suffers considerable losses.

Before making an investment decision, however, it is suggested to consider the prospects of return on said investment and the chosen priorities of the economic development of the farm. The investment costs of germination equipment, depending on the applied technology, amount to about €300 per animal, reconstruction and adaptation of the premises for growing sprouts is about €120 per animal. According to the approved standards, when the depreciation period of a building is 15 years, that of hydroponic equipment – 5 years, the depreciation cost of an investment per 1 kg of the feed is about €0.03, thus investments pay off in 3–5 years, depending on the size of the farm, production intensity, use of technology, and intensity of financial support.

ECONOMIC EFFECT AND OFFERS TO APPLY INNOVATION

1. The investment costs of germination equipment, depending on the applied technology, amount to about €300 per animal, reconstruction and adaptation of the premises for growing sprouts is about €120 per animal. According to the approved standards, when the depreciation period of a building is 15 years, that of hydroponic equipment – 5 years, the depreciation cost of an investment per kg of feed is about €0.03, thus investments pay off in 3–5 years, depending on the size of a farm, production intensity, use of technology, and the intensity of financial support.

2. According to the test results, the production cost of a kilogram of sprouts ranges from €0.06 to €0.12. A major part of the direct costs of growing them consists of seed acquisition costs and staff salaries. Seed costs depend on the sprout type and account for up to 35–45% of the direct costs. The cheapest are barley seeds (0.19 Euro/kg) while the most expensive are alfalfa seeds (up to 4.90 Euro/kg). Therefore, the use of farm-grown grain seeds may lead to lower feed costs. Employee salaries represent up to 20–30% of the total cost of growing sprouts. A large hydroponic feed production system requires two skilled full-time workers to produce 2 tons per day. Larger farms can be equipped with a fully automated robot that does not require workforce and, therefore, does not impose labor costs, however, the system itself is more expensive.

As for the indirect costs that make up the production cost, the highest ones are related with heating and microclimate maintenance (14–23%). However, their share in the cost of 1 kg of feed decreases when hydroponic equipment is used more intensively.

3. The economic effect when using germinated grains for fattening cattle and dairy cows is achieved in two ways: (a) supplementing conventional rations with germinated grains to increase productivity and income; (b) replacing a part of expensive compound feed with sprouts in normal conventional ration to reduce the production cost without reducing productivity and income.

4. During the experiments, the addition of germinated grains to rations increased the total cost of production due to the need to produce an additional feed additive but increased productivity and revenue. In this case, supplementing the ration with 2 kg of germinated grains for the experimental groups of cattle, the cost of 1 kg of weight gain increased from 1.4–1.7% (when germinating peas, wheat, and barley) to 7.8% (when germinating alfalfa) than that of the control group. Similarly, the cost of 1 kg of milk from the experimental cow groups was 2–6% higher than that from the control group of cows. In both cases, however, the economic effect was achieved due to an increase in weight gain or milk productivity. To assess the economic effect, the income ratio between the sales revenue and the total expenditure due to the increase in weight gain or milk productivity and the productivity of the control group is expressed as a percentage.

5. Having compared the average weight gains of the fattening cattle from the experimental and control groups, the average daily weight gain of the former group of cattle, whose ration was supplemented with sprouts, was higher but differed significantly from farm to farm and from test to test as well as when applying various grain seeds.

6. The addition of sprouted grains to the ration of fattening bulls caused a faster weight gain of 9.4–19.3%, resulting in the economic effect of about 8–14%. The mixture of sprouted wheat and barley (50:50) had the greatest influence on the weight gain of bulls. Thus, it is recommended for wider use. The most significant influence of germinated grains on the weight

gain of bulls is before they are 14–15 months old, and the fastest one – in the first five months of their lives, when the effect of weight gain reaches as much as 30.4% when supplementing their ration with a mixture of sprouted wheat and barley (50:50).

Control weighings	Groups							
	Control		Alfalfa		Wheat, barley		Peas	
	Weight, kg	Gained over the period, kg	Weight, kg	Gained over the period, kg	Weight, kg	Gained over the period, kg	Weight, kg	Gained over the period, kg
I	394.9	30.6	435.2	29.4	413.3	38.4	-	-
II	410.2	16.0	456.2	21.0	47.9	24.6	457.0	18.2
III	431.0	21.0	484.2	28.0	465.2	27.0	485.0	28.0
IV	463.0	32.0	508.0	23.8	491.0	25.8	517.0	32.0
V	486.0	23.0	544.0	36.0	527.0	36.0	549.0	32.0
VI	503.0	17.0	559.0	15.0	546.0	19.0	565.0	16.0
VII	512.0	9.0	579.0	20.0	552.0	6.0	583.0	12.0
VIII	552.0	40.0	626.0	48.0	594.0	42.0	621.0	38.0
IX	575.0	23.0	636.0	10.0	611.0	17.0	631.0	10.0
X	592.0	17.0	670.0	32.0	640.0	29.0	651.0	21.0
In total	-	228.6	-	263.2	-	264.8	-	-
Average per stage	-	22.9	-	26.3	-	26.5	-	23.0

Table 3. Weight dynamics of bulls in control and experimental groups.

7. In addition to the direct economic effect, supplementing the ration with sprouts has a positive effect on other important indicators that affect the cattle or meat value. Sprouted alfalfa and pea seeds had the greatest influence on meatiness indicators. The bulls fed with them had a higher carcass yield (1.21 and 0.59 percent, respectively) from the hip-thigh part of the carcass, where the meat is the most nutritionally valuable. Moreover, the addition of germinated cereals to the ration of bulls had a positive effect on the fatty acid structure of the meat (the content of unsaturated and harmful fatty acids in the meat of the animals fed with sprouts was 13.78–15.70% or about 1.8 times lower than that of the control group bulls).

8. Although the addition of sprouted alfalfa seeds is quite effective in terms of production quality, especially at the end of the fattening period, its use can be expensive due to a high seed price (about 4 Euro/kg), which significantly increases the cost of feed production compared to traditional feed rations (the increase of 7–8%) and reduces the economic effect. It is recommended to use peas as inexpensive seed material to mix with barley, wheat or their mixture.

9. Based on the project experience, it is proposed to add 2 kg of germinated wheat and barley mixture (50:50) to the main ration to increase the growth rate of bulls raised for meat before they are 14–15 months old and 2 kg of sprouted peas to improve meatiness and meat quality. To obtain beef of a very high biological and nutritional value, 2 kg of germinated alfalfa seeds (the need for high quality justifies a relatively high cost) should be added to the main ration every day.

10. According to practical experience in the use of sprouted grains in US farms, it is possible to gradually increase the proportion of sprouts in the ration of fattening bulls up to 10 kg

per day, completely replacing grains or concentrated feed. This can reduce the cost of production and even obtain up to 20–30% of the direct economic effect.

11. Having compared the increase in milk yield of the experimental and control groups of dairy cows during the experiments, the average milk yield of cows, the rations of which had been supplemented with 2 kg of sprouts, was 4 to 33% higher. However, it varied greatly from farm to farm and from trial to trial, as well as when using different grain seeds. The most reliable research data show that the addition of 2 kg of germinated barley or triticale, a mixture of triticale and barley, a mixture of barley and peas, or sprouted wheat to the ration of dairy cows produces an average of 8–17% more milk per month compared to the control group cows. The estimated economic effect, taking into account the increase in sales revenue and the cost of producing additional feed, is 6–15%. In individual cases, good results were achieved by supplementing the ration with additional bean or oat sprouts, obtaining 10 or 17 percent extra milk yield. However, germination of these seeds is not advisable due to insufficient weight increase in bean sprouts during germination or poor germination of oats.

12. Based on the experience of the project, it is proposed to add 2 kg of sprouted wheat and barley (50:50) mixture or sprouted beans to increase milk yield, milk fat and protein per cow. 2 kg of sprouted peas or beans could be added to the main ration to increase milk yield, milk fat and protein obtained per cow. The use of peas is practically acceptable, however, the use of beans is less attractive due to the lower sprout weight obtained during germination compared to other types of grain.

13. In order to reduce the production cost, concentrated feeds can be replaced with sprouts. According to the project, replacing 2 kg of concentrated feed with 4 kg of barley and wheat sprouts, the cost of which per kilogram is at least twice as low, can produce about 8% extra milk yield. Adjusting the feed at this ratio will not change the feed cost, but the resulting additional milk yield will produce the economic effect of 8%.

14. Practice and production testing when the concentrated feed was replaced with wheat or barley shoots at the ratio of 1: 1, i.e. 1 kg to 1 kg or 2 kg to 2 kg, allow expecting a reduction of milk production costs by at least a few percentage points while maintaining a similar milk yield. However, sprouts must be of good quality.

15. This change is also beneficial in terms of land use. The saved land is usually used to grow feed grains, thus it can now be used to grow commercial higher value-added food grains. According to the experience of individual project partner farmers, on a large dairy farm this results in an additional economic benefit of 1–3 % that can be added to the economic effect of milk production.

16. Before deciding to implement these innovations, we suggest taking into account, other benefits identified by the farmers involved in the project, which are difficult to assess in terms of the direct economic effect:

- Feed supply is more even, regardless of the season and climatic conditions;
- For highly productive animals balancing feed with rations is difficult because, for example, increasing the amount of grain alone would not have an effect. The vertical hydroponic system produces fresh, balanced feed that is acceptable and most beneficial to the animal;

- Milk quality indicators are noticeably better: more protein, fat, lactose while the milk is tastier;
- Health indicators of cattle are noticeably better because sprouts are rich in biologically active phytohormones and various minerals, which are easily absorbed by the animal's body;
- There is a clear improvement in the insemination rates of cows, which brings additional economic benefits as farms use expensive, high-quality breeding bull semen produced in the US. Thus, if a farm must inseminate several times, it suffers considerable losses.

17. When implementing the innovation, it is recommended to assess that the successful production of hydroponically grown feed depends on the quality of the germinated seeds: their germination, germination energy, and microbiological contamination. The optimal germination temperature is 21–22 °C, relative humidity – about 60-70%. Watering with a nutrient solution reduces the dry matter loss, however, germination does not affect the seed weight increase of all species of plants. The increase in grain weight is influenced by a complex of factors such as germination temperature, relative humidity, the number of watering's per day, seed type, and varietal characteristics. As the germination time of the seeds increases, the content of dry and non-nitrogenous substances, which are easily absorbed by the animal's body, decreases. It is necessary to use human, animal and environmentally friendly means to disinfect germinated seeds. The choice of seeds to be germinated also depends on farm resources, crops grown on the farm, cattle, and the planned economic effect.