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MODERN TECHNICAL AND TECHNOLOGICAL SOLUTIONS EMPLOYED IN MILK PRODUCTION

NOWOCZESNE ROZWIĄZANIA TECHNICZNO-TECHNOLOGICZNE STOSOWANE W PRODUKCJI MLEKA

Summary: *The aim of the present paper was to analyze the modern technical and engineering solutions, utilised in milk production and their effect on development of dairy farms. The analysis was carried out on the grounds of literature review. The data concerning the cow population in Poland, milk market were submitted and modern technologies in farm buildings (milk barns) were described. It has been demonstrated that livestock buildings and modern solutions are the important element, ensuring as high welfare level of the dairy cattle.*

Keywords: *agriculture, cattle, housing systems, feeding systems, milking systems, modern solutions*

Streszczenie: *Celem niniejszej pracy była analiza nowoczesnych rozwiązań techniczno-technologicznych stosowanych w produkcji mleka i ich wpływ na rozwój gospodarstwa na podstawie przeglądu literatury. Przedstawiono dane dotyczące pogłowia krów w Polsce, rynku mleka oraz opisano nowoczesne technologie w budynkach gospodarskich (oborach). Wykazano, że bardzo ważnym elementem zapewniającym wysoki dobrostan bydła mlecznego jest budynek inwentarski i nowoczesne rozwiązania. Przekłada się to na wyniki produkcyjne i ekonomiczne.*

Słowa kluczowe: *rolnictwo, bydło, systemy utrzymania, systemy karmienia, systemy doju, nowoczesne rozwiązania*

Introduction

Dairy cattle husbandry in Poland is one of the basic sectors of agricultural production and the participation of cow milk in the purchase of animal products is 77.9%. Jankowski and Sosnowski [12] inform that specialization of farms and production concentration, the increasing size of dairy herds as well as increase of milk cow performance are the factors which make that milk production is a stable and permanent source of farmer's incomes.

Milk production is the most important branch of agricultural economy in Poland and it plays a role of raw material source for the dairy industry. Milk products are the indispensable raw material for food and pharmaceutical industry. Polish dairy industry has adapted for many years to varying market conditions which, in effect, resulted in production concentration and milk processing. Modern technological resources, a high quality of raw milk and dairy products have contributed to competitiveness of Polish industry on the international market. The competitiveness of West-European agriculture which is highly productive as well as the necessity of keeping high sanitary and veterinary standards and of detailed understood animal welfare, implementation of the national programme of compensations paid to smaller producers for giving up milk production and, also, economic turbulences at the global market, are the factors which also have contributed to concentration of milk production in Poland [24].

Milk production is, however, dependent to a great degree on climate conditions, including the amount of precipitations and the length of plant vegetation period. Parzonko [2013] informs that in Poland there are good natural conditions cattle breeding and milk production due to its favourable location in a moderate climate zone. The lowland territories which are dominating are the perfect habitat for cultivation of fodder plants, used in cow feeding.

The costs of milk production in the dairy farms are undoubtedly the aspect determining milk production profitability [23].

The cows reach sexual maturity at the age of 1.5–2 years and then, they are subjected to insemination. Gestation lasts for 9 months during which milk udders commence milk production. After parturition, the cows produce milk, which is rich in nutrients, minerals and antibodies. It is colostrum which is not suitable for human consumption; therefore, the cows are not milked in the mentioned period. Milk is very valuable for a calf

because it determines his immunity. To increase the yield of the produced milk, the cows are again inseminated after 90 days from the parturition; then, irrespectively of their physiological state, they are still milked. About the 7th month, the drying period is commenced, i.e. the cows are not milked in order to become stronger before the next delivery.

In 2021, in spite of the decrease of cow population, the mean milk performance was increased; it varied at the level of 6540 litres per head. It resulted in 14.4 billion litre of the produced milk [12, 24].

To reach good results in milk production, a widely understood progress in necessary. It has been noticed for many years in cattle management and production of high quality milk. The development of modern technologies which are connected with rearing of dairy cattle and milk production is to-day the integral part of Polish agriculture. The appropriate application of modern tools and modern technologies, opening to all innovations mean improvement of manufacturing processes and facilitation of undertaking the decisions being most important for the farmers. Due to the fact that a dairy cattle breeding is especially hard and labour-consuming work, the utilization of modern tools and widely understood progress allows the considerable improvement of milk production economics and, by this, reaching higher profits at the lower labour outlays [24].

The farmers, who have observed the changes on the dairy market and the changes in the effective management, are aware that the already made investments, or those ones anticipated for the nearest future, have and will have the meaningful influence on profitability of milk production in the future.

Literature review

Dairy cow population and milk market in Poland

Milk production is one of the most important production sectors in Poland. Due to the fact that it is a source of existence of many agricultural farms and is the basis for the national dairy industry, it has a great economic meaning. The products coming from milk processing (dairy products) are the indispensable raw material in many domains, not only of food industry but also, of pharmaceutical and cosmetic industries. Polish dairying has followed for many years the varying market conditions, what brought about to the present concentration of production and processing of milk. The modern technological basis and high quality of the raw milk are the factors of the competitiveness of Polish dairy industry at the international market [14, 23].

Poland occupies the third place (after Germany and France) in the ranking of the dairy cow population in the European Union, although in 2020, a small decrease of the number of cows was observed. the data of the Main Statistical Bureau (GUS) show that in June 2020, the population of dairy cow varied at the level of 2 218 000 heads and one year earlier, in 2019 – it was 2 222 436 heads. Diagram 1 illustrates the level of dairy cow population in Poland in the years 2004–2020.

The data found in Figure 1 show the decrease in dairy cow population since 2008. In 2014 and in 2015, dairy cow population amounted to 2.3 million cows whereas in 2015 it was decreased to 2.1 million heads.

Due to different reasons, including those economic and environmental ones, milk production in Poland is concentrated in its east and central parts (Figure 2).

At the territory of the Mazovian Voivodeship, it comes from 22% of the total dairy cow population; in the Podlaskie Voivodeship – 20%; in the Wielkopolskie Voivodeship – 14%; in the Łódzkie and Warmia and Mazury Voivodeships – 8% in each; in the Kuyavyan-Pomeranian Voivodeship – 6% and the Lubuskie Voivodeship – 5%.

The mentioned above voivodeships include more than 83% of the total number of national dairy cattle population and the implementation of milk supplies at their territory oscillates around 86%.

The lowest percentage of dairy cows in Poland in 2020 was found in the Lubuskie Voivodeship (13%), Low-Silesian Voivodeship (25%) and West-Pomeranian Voivodeship (27%).

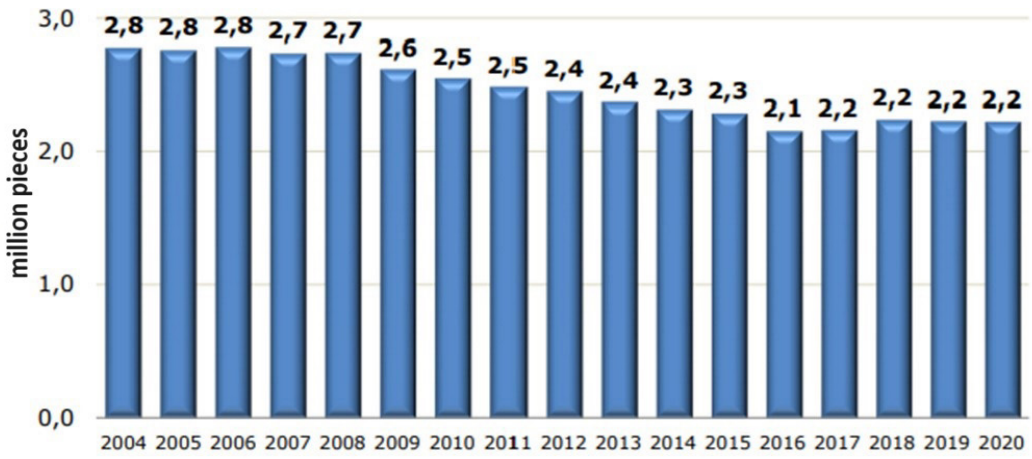


Fig. 1. Dairy cow population in Poland in the years 2004-2020
Source: KOWR 2021 [13]

In the table, the population of dairy cows in the years 2013 – 2020 in the particular voivodeships has been presented.

The analysis of the data contained in Tab.1 allows the confirmation that the population of the dairy cows in the earlier mentioned voivodeships is the highest one. We may also see the relationship of the level of cattle population in the particular voivodeships in 2020 as compared to 2019. It

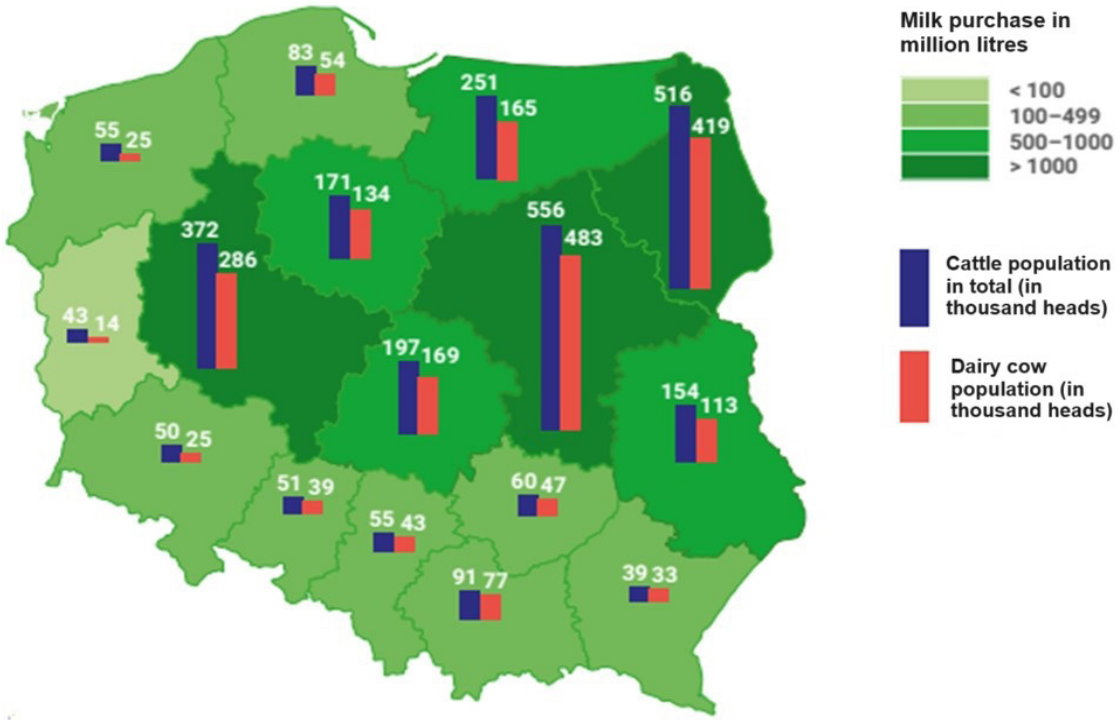


Fig 2. Cattle and dairy cow population and milk purchase in Poland in 2020 in the particular voivodeships
Source: KOWR 2021 [13]

Table 1. Population of dairy cows in 2013-2020 in the particular voivodeships in Poland

POLAND	2013	2014	2015	2016	2017	2018	2019	2020	Change,% 2020/2019
	2.361	2.310	2.279	2.146	2.154	2.233	2.221	2.218	-0.2
Low-Silesian	32	32	30	28	27	27	26	25	-6.7
Kuyavyan-Pomeranian	152	148	155	151	136	152	158	142	-10.0
Lubelskie	145	145	142	130	133	127	122	119	-1.9
Lubuskie	18	19	14	13	15	15	13	13	-1.3
Łódzkie	187	200	185	175	177	183	182	180	-1.1
Małopolskie	94	85	84	82	75	81	76	80	4.6
Mazovian	518	515	490	458	468	500	539	498	-7.5
Opolskie	40	41	40	40	38	40	38	38	6.0
Sub-Carpatian	59	54	53	48	45	42	36	36	0.3
Podlaskie	449	428	445	415	434	443	432	436	1.1
Pomeranian	66	64	62	58	59	60	55	58	5.0
Silesian	46	44	43	42	42	43	43	45	2.9
Świętokrzyskie	61	59	59	53	51	51	47	47	-0.1
Warmia and Mazury	176	180	172	167	171	185	462	171	5.7
Wielkopolskie	292	267	277	261	261	261	162	171	11.6
West-Pomeranian	25	27	26	25	22	23	23	27	13.9

Source: KOWR 2021 [13]

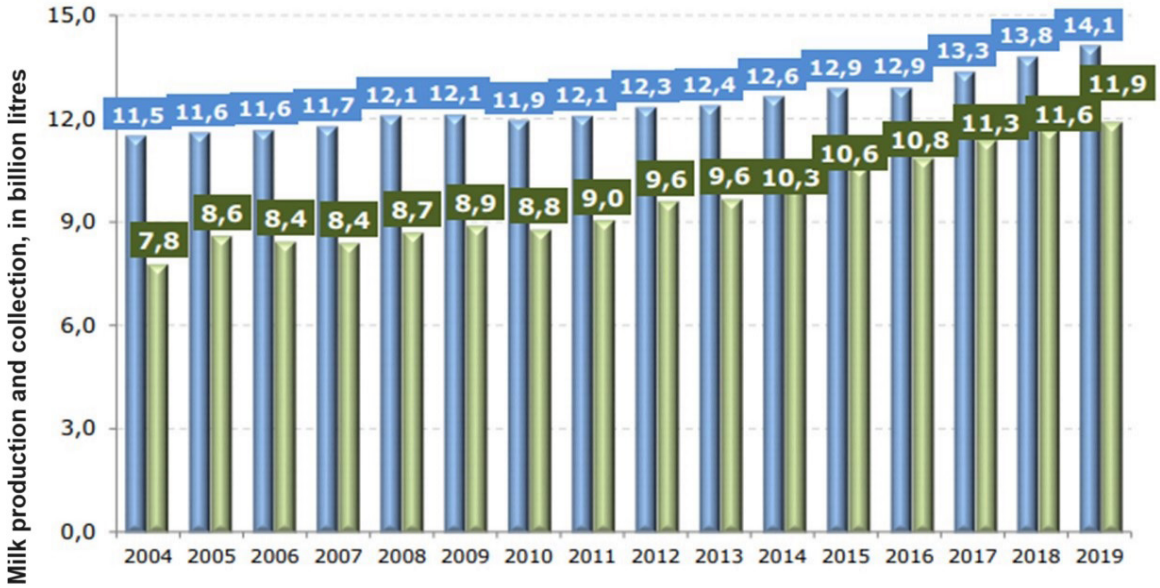


Fig. 3. Milk production and collection in Poland in the years 2004-2019
Source: KOWR 2021 [13]

was increased the most in the Opolskie, Warmia and Mazury and Pomeranian voivodeships. The greatest decline was found in the Kuyavyan-Pomeranian and Mazovian voivodeship.

Poland is found at the top of the meaningful milk producers; it occupies the 5th place in the EU and the 12th place in the world. The national dairy industry has a significant participation in GDP generation by the agricultural sector. Milk production in 2019 reached the level of 14.1 billion litres and it was higher than in the preceding year.

Diagram 3 shows milk production and collection in Poland in the years 2004–2019.

In 2020, milk collection was found at the level of ca. 8.3 billion litres whereas in 2021, the market entities collected 1.022 million litre of raw milk in September. In 2021, the prices of milk were shaped at the level of 150.52 PLN/hl, i.e. by 13% higher than in 2020. The highest prices were obtained in the Podlaskie Voivodeship (153.77 PLN/hl) and in the Lubuskie Voivodeship (153.39 PLN/hl). The lowest prices for milk were paid in the Małopolskie Voivodeship (138.01 PLN/hl and the Łódzkie Voivodeship (142.13 PLN/hl). The population of the dairy cattle in December 2021 oscillated at the level of 2 289 thousand heads [18].

In 2021, milk collection was equal to 12 117 million litres; a little more than in 2020. The greatest declines were observed in the Warmia and Mazury Voivodeship (607.5 thousand litres), in the Kuyavyan-Pomeranian Voivodeship (536.8 thousand litres) and the Wielkopolskie Voivodeship (456.7 thousand litre). The greatest quantity of milk from other voivodeships came to the Podlasie. The mentioned amount oscillated at the level of 1 902 million litres [15].

The average price of milk collection in 2021 (for 12 months) amounted to 157 PLN/hl and was somewhat higher than the price in 2020 [18].

Infrastructure and modern technologies in the farm buildings – dairy barns

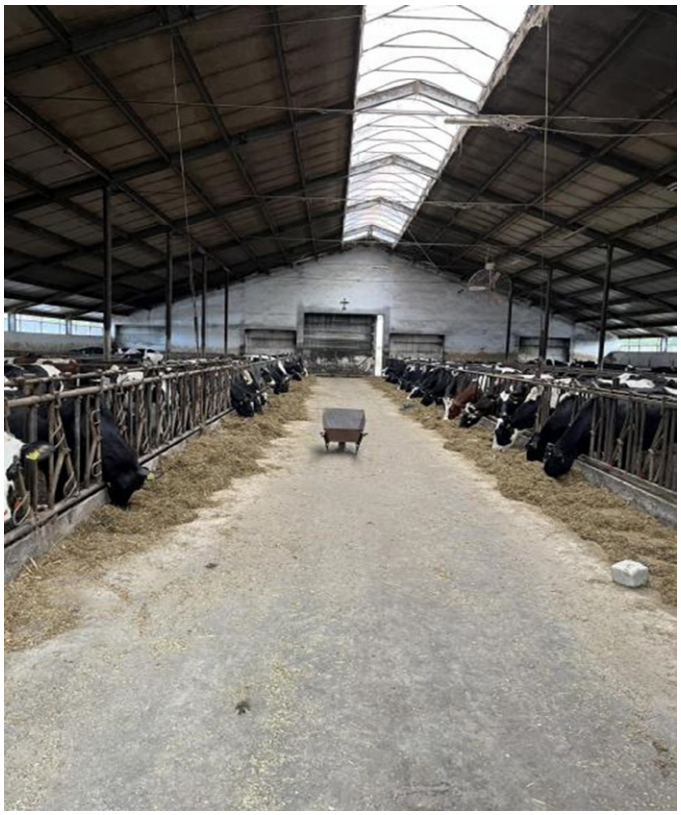
Dairy cattle husbandry as well as the production and economic effects of the mentioned management are strictly connected with the structure of agricultural farms which are specialized in the discussed production [3].

The contemporary milk production in the commercial scale is characterized by the application of more and more modern technical infrastructure and the solutions, being the premise for a high yield and limitation of labour outlays as well as improving the quality of the obtained milk [1].

Agricultural practice show that the utilization of the potential of modern equipment and technologies is fully justified in each zone of the milk barn, including also the area of milking [17], removal and collection of manure [6] as well as in preparation and administration of feeds [7]. On the other hand, Fiedorowicz and Mazur [6] pay attention to the microclimate conditions in the livestock buildings.

In the system of the dairy cattle housing, we may distinguish two basic solutions of keeping the cows in the barns: tying stalls and loose housing. When choosing the type of dairy barn, we take the size of the herd, economic conditions, animal welfare, and safety of work into consideration. If the stocking density of the cattle herd is 30 heads, the cost of building the loose housing barn and tying stall is similar. The difference can be visible in the case of 60 animals, in favour of a loose barn [29].

Loose housing barn has many advantages and the animals are kept in the way similar to the natural one what is very favourable for their performance. In the discussed barn, the cows have a freedom of moving and a contact with other cows. Milking is carried out in the separate premises. From among the



Fot. 1. The cows in a loose barn
Source: photography of the authors

Fot. 2. The cows in the tying stalls
Source: photography of authors

loose barns, we may distinguish the following types:

- with the separate part for feeding, with a deep litter and with the collective laying part;
- with boxes which meet the feeding and laying function simultaneously;
- with the separate part for laying and for feeding.

The loose barns facilitate getting up and down of the cows in their specific way and the number of stalls must be adequate to the number of animals. The loose barn with the deep litter consists of two parts, separated each other with the steps: for lying and for feeding, with the dimensions of 3–3.5 m. The surfaces of the beds must be adapted to the number of the kept animals provided that there is 5 m^2 of bed per each animal. The litter may be employed on the beds but there are also used slotted floors. Boxes in the barns must give the possibility of free moving for the cows; the floor may have a litter or may be litter-free. In the latter case, a plastic matte may be used. In situation of kombi-boxes, feeding is carried out on laying bed. The kombi-boxes are situated on two sides of feeding corridor and they are adjusted to the size of animals (110–120 cm x 170–180 cm).

A special attention should be paid to the standings in tied type of barns as they should not be too short or narrow because they lower the condition of the cow and restrict her movements.

The tether must give the possibility of forward movement for the cow, free standing up and lying down and backward movement. The length of the tether must force the cow to keep the head over the feed trough when lying. If the standing is slotted, it must protect from damage of udders. In such barns, the standings are long and short. In the case of litter-free floor, they are usually short (180–190 cm). They are selected in such a way that the legs of the cow are at the distance of 10 cm from the edge. Keeping such distance makes that the faeces of the animal will pass to the manure channel.

Long standings (210–250 cm) are recommended for parturition or for treatment. They are more difficult in respect of keeping cleanness and in the contaminated standing, soling of the udder and mastitis occur more frequently.

The modern buildings, as adjusted to animal needs, have to ensure for the animals:

- appropriate lighting coming from the day or artificial light;
- the required air exchange;
- keeping the appropriate temperature;
- safety and protection from unfavourable atmospheric conditions;
- protection from humidity from the floor and the accumulated animal faeces (manure);
- removal of slurry from the standings, presence of installations and equipment adapted to the destination of the premises;
- the appropriate conditions for service and care.

In the agricultural farms, specialized in cattle breeding and milk production (dairy farms), the equipment for supply of feeds are indispensable. The correct organization of feeding facilitates the service of the herd and saves the time of work in the farm [19].

The mixing feed wagon is the equipment which makes the work considerable easier. It has the application in two technologies of cattle feeding; in TMR and PMR system. TMR system supplies the complete feeding ration, fully mixed, the composition of which includes maize and straw silage, haylage from grass, concentrate and feed additives. The ration is completely mixed; the cow has no possibility to choose the bites but she eats the whole portion. PMR system supplies the lower quantity of feed components to the cow [2].

Application of feed wagon causes a rapid and effective preparation of feed for animals and its precise dosage. The discussed equipment mixes accurately the components of the feed and makes that they are not subjected to lumping. It occurs owing to its robust construction, based upon the significant elements. Bulk storage container which is made from a thick sheet metal plays the important role as the feed is prepared inside it. It should be resistant and capacious and the mentioned capacity should be adapted to the needs of a given farm. Its shape and dimensions must be so selected as to prevent feed loss and facilitate its precise mixing [10, 26, 27].

The mixers (agitators) and knives are the successive necessary elements of feed wagon, which guarantee a precise cutting and accurate disintegration (grinding) of feed composition. The mentioned elements have also influence on the readiness of the cows for consumption of feed. Therefore, grinding of the feed is the element which affects the effectiveness of milk production in the indirect way. Due to intensive use, the edges of the knives are subjected to a quick wear, they may become dulled; therefore, they should be controlled and depending on the needs, replaced [30, 31].

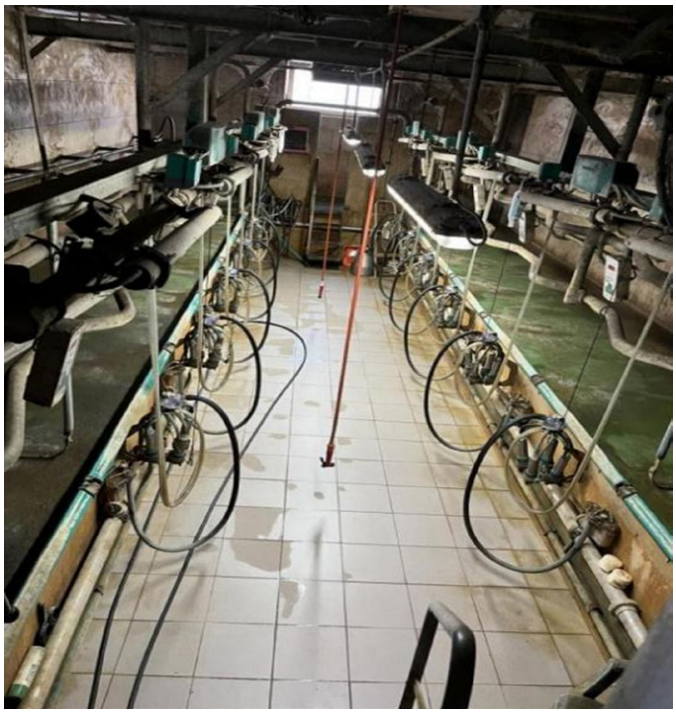
Feed wagons not only mix and comminute the feed but also facilitate its supply to the cows in a direct way. It is possible owing to the equipment of machine in the special discharge openings or the tapes (belts) which ensure the uniform and effective dosage of feed.

The feeding station, adjusted to automatic feeding has a great meaning in feeding of the cows. It consists in adaptation of the quantity of administrated concentrates to the needs of individual cows, equipped with the so-called transporters. With the help of the mentioned equipment, the reader if the feed station identifies the animal, so each of the cows receives the precisely measure amount of feed. The work of the feed station is steered by the computer system; owing to this fact, the time-consumption of feeding becomes considerably limited. The agricultural practice recommends the application of one feed station for 25–30 animals in loose barn system, with one programme, controlling the work of four stations [11, 27].

The most important equipment in preparation and administration of feed in cattle feeding system include as follows [2, 7, 20]:

- knife cutter of silage;
- jaw selector of silage;
- selector of silage with loading box and feeder for supply of feed;
- wagon for loading and disintegration of bales and supply of hay or straw;
- stationary chopper of bales;
- electric cutter of bales;
- trailer cutter of straw or hay bales;
- developer and spreader of straw;
- chopper of straw bales with spreader.

The modern technologies in dairy cattle management are connected with milking. Manual milking has become replaced by mechanical milking of cows. Głowacka-Wołoszyn et al. [8] inform that such milking has the influence on improvement of the quality and quantity of the obtained milk. During the milking in tying stall system, there are employed bucket milking machines and pipeline installations.



Fot. 3. Milking parlour of "herringbone" type
Source: photography of authors

During milking with the application of churn milking machine, the milk is collected in the bucket and after filling, it is poured to cooler. On the other hand, in the case of milking with the use of pipeline milking machines, the milk is transported to cooler by pipelines.

In the loose stall systems, milking is performed mainly in the milking parlours, differing in the number and situation of milking stands. The output expressed as a number of the milked cows by the milkman at the time unit [16, 25] is the important element of milking parlours.

The mentioned milking parlours are the premises where milking of cows is carried out with the application of milking machines. Owing to this equipment, obtaining and treatment of milk coming from a few or several dozens of cows is decisively less labour - and time-consuming. The milking parlours make the work easier, more comfortable and more effective. It allows milking 9 cows per hour at one milking stand and in the more modern milking parlour it is possible even to milk 18 cows per hour at one stand [22, 25].

We may distinguish a few types of milking parlours:

- "herringbone";
- "tandem";
- "rotary ("carrousel");
- "side-to-side" [2].

Milking parlours of "herringbone" type are offered in two versions: -30° – the cows are milked from the side and 60° – the cows are milked from the rear. Each of the mentioned versions ensures the milkman a perfect access to the animals and the

distribution of the milking stands guarantees the optimal and convenient position for the cow and for the milkman. The milking stands are adapted to the anatomic condition of the cow. The construction of the milking parlour itself is integrated with the components of milking technique.

The milking parlours of "tandem" type are characterized by side position of the cows during the milking. The cows stand at the separate stands and the milkman may freely observe the whole herd. Such type of milking parlour allows individual treatment of the cows, easy control of the state of their health and allows quick noticing of all irregularities in cow.

"Carousel" is a sort of milking parlour, it is very practical for big herds; it has 12 or more milking stands. The performance of the discussed type of milking parlour is 100–120 cows per hour for one milkman and for two – the milking performance is increased up to more than 200 cows per hour.

The milking parlour of "side-to-side" type is distinguished by the parallel arrangement of the cows next to each other and milking is carried out from the rear. It gives the possibility of easier attachment and take–off of the cluster of the milking machine. Position of the cows during milking abbreviates the dimensions of the milking parlour, and by this, the distance which the milkman has to pas during milking. The cows leave the milking parlour via the rotary gate, rotating by 180°, or 360°. The baffles or fencing in the milking parlour ensure comfort to the cows and the labour efficiency to the operator. The main advantages of the discussed solution include the system of a quick exit, easy access to the cows and convenient milking.

In every agricultural farm, the tractors are the necessary equipment. Their purchase is connected with the investing capital for many years. The trailers are employed in different types of work:

- general work in farm (supply with production means, sale of the products, work at the yard of the farm);
- field work.

The demand on tractors with different equipment is greatly differentiated in terms of 100 farms as well as per 100 ha of agricultural land. It is connected with the territorial distribution of the farms, according to their area.

In each farm, there are tractor loaders, serving for daily removal of manure from the slurry channels, removal of manure from the barns with a deep litter, formation of prism at the dung yard, loading of spreaders of lime and fertilizers, work which is connected with movement of silage, straw and hay etc. The loaders work as fitted to the trailers or they are suspended. The front-end loaders are most frequently employed [9].

The farms are also equipped with trailer forklifts (loaders), facilitating lifting the loads, placed on pallets or in the containers. They give the possibility to move them into small distances, and later, placing them on low agricultural trailers. Load capacity of the lifts oscillates within the limits of 600–1400 kg and the height of lifting up is 1.8–2.7 m. The discussed equipment is suspended at the supporter of the front axis of tractor. The rear lifts are placed on the three-point system of suspension of the tractors [2].

Within the farms, there are also many other machines or equipment employed such as ploughs, harrows, skinning aggregates, spreaders of fertilizers, spreaders of mineral fertilizers, spreaders of manure, slurry tankers, cereal drills, single-seed drills, field sprinklers, mowers, grain combine-harvesters and others.

Szewczyk [28] informs that the level of technical equipment of agricultural farms is determined by agrarian structure of the region, structure of cultivations or commodity range of the farms.

We should also pay attention to monitoring which may be considered as a certain modern technology in agriculture. Monitoring in the agricultural farms has a greater and greater meaning. The systems of monitoring, situated in the barns must, however, be characterized by the increased resistance of the equipment due to unfavourable environmental conditions which occur in the barns. High nitrogen concentration is greatly unfavourable for electronic components and has a negative effect on the time of their failure-free work. A high effectiveness of failure-free work may be obtained owing to the appropriate choice of the equipment which meets the severe standards of tightness IP.

Monitoring in the agricultural farms plays the important role and is a quickly returnable investment. Installation of cameras brings many advantages and one of them includes protection of agricultural machines from vandals and thieves. The monitoring not only protects the property of the farmers but also helps in breeding of animals which requires day-and-night care, e.g. waiting for parturition, the possibility of passing outside the farm or in the case of disease. All this may be controlled from the outside of the barn, even outside the farm. the correctly chosen equipment, ready to work under the difficult conditions, stores the records of the events for a long time; owing to this fact the farmer may prove his arguments if needed, before respective institutions or insurers.

Discussion

After the accession of Poland to the European Union, many farmers had to modernize their farms because in the member states of the EU a high attention is paid to the animal welfare. Most of the barns before 2004 did not meet the requirements of the contemporary technologies and did not ensure the correct conditions for management of the herd. Besides it, a high quality milk production requires time and attention. It necessitates also health and welfare of animals, and undertaking the appropriate decisions in accordance with the aims of the breeders.

Dairy husbandry in Poland is the most important agricultural sector of economy. Borusiewicz and Kapela [4] state that high performance of cows, together with the optimally low labour-consumption of handling with the animals is the basis for profitability of raw milk production.

The authors add that in the case of dairy cows, apart from feeding which decides on cattle productivity, the conditions of animal life as well as genetic determinants of milk performance, are the significant elements.

Neja [21] believes that the livestock building is the basic element of animal protection; this opinion was also confirmed by the owners of farms where the studies were carried out.

Many breeders and researchers express the opinion that loose barn system of management as compared to tying stall system has the advantage in respect of animal welfare and mechanization and automation of work, especially of milking. The loose barn system ensures also integration of animals within a group and, also, the unlimited movement in the barn. For the attendants, the work is also easier.

Conclusions

On the grounds of the analysis of literature and the available data, we may formulate the following conclusions:

1. The livestock building together with the modern solutions which improve behaviour of animals is a very important element of cattle protection and its health state
2. Modern technological solutions abbreviate the time of work of the farmer and increase the performance of the cattle
3. Installation of modern solutions in the barns is equivalent with obtaining the optimal conditions of cattle welfare and milking hygiene. It is reflected in production and economic results.
4. Computerisation and monitoring are the factors which make the work of the farmers much easier and improve simultaneously the safety of the herd. The users of computer programmes and monitoring have the permanent access to all information as well as parameters concerning quality and quantity of milk and health state of the herd.

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