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INFLUENCE OF SCALE SIZE ON THE PROFITABILITY OF COW'S MILK PRODUCTION

ALDONA SKARŻYŃSKA

Abstract

The issue of profitability of the agricultural production is often discussed within the framework of the problems of agricultural economics. The study showed a diversification in the profitability of the milk production depending on the cow herd's size and identified the main determinants of positive economic results. The studies were conducted on commodity farms, which have been grouped according to the production scale, the criterion of scale was the number of dairy cows in the herd. Three scale ranges have been identified, i.e. small, medium and large. The data of 2014 and 2017 was used for the analysis. What was examined was the effectiveness of feeding cows in the identified farm groups and the technical and economic efficiency of the milk production. The full costs of the milk production (i.e. economic costs) were assessed and income from management activity was calculated.

The results of the analyses show that as the number of cows in the herd increases, their milk yield and the price of milk are increasing. Farms with a large number of cows in the herd incurred the lowest full costs of the milk production, while obtaining the highest income from management activity per 1 cow and per 1 litre of milk. The measure of the milk production's economic efficiency was the profitability index (revenues-to-economic costs ratio), the highest was recorded for the large-scale milk production, for the small scale this index did not exceed the profitability threshold.

Keywords: profitability of milk production, production scale, unit costs.

JEL codes: D24, O13, Q12.

Dr hab. Aldona Skarżyńska, prof. IERiGŻ-PIB, Institute of Agricultural and Food Economics – National Research Institute, Department of Economics of Agricultural and Horticultural Holdings; ul. Świętokrzyska 20, 00-002 Warsaw (aldona.skarzynska@ierigz.waw.pl).
ORCID iD: 0000-0003-0912-0837.

Introduction

In Poland, the agricultural commodity production is dominated by the livestock production, in the years 2014-2017 its share was between 58.2 and 60.7%. In this section, an important branch is the milk production which accounted for 27.2-31.6% of the commodity production (GUS, 2015, 2018). The rearing of dairy cattle and milk production play an important role in generating income, both for farms keeping dairy cattle and agriculture as a whole.

According to the results of the farm structure survey (GUS, 2017), conducted in 2016 among farms keeping dairy cows, the most numerous were those which kept only 1-2 cows. The share of those farms in the entire sample of farms keeping dairy cows was 43.7%. By contrast, farms which kept 3-9 cows accounted for 28.3% and those with 10 cows and more – 28.0%. Taking into account the utilised agricultural area (UAA) and the scale of cow rearing, in groups of farms keeping 1-2 and 3-9 cows small entities were most numerous. Those were farms with an area of 5-10 ha of UAA, in the above-mentioned groups (identified according to the scale of cow rearing) they accounted for, respectively, 34.2 and 33.4%. On the other hand, among farms keeping 10 cows and more, units with an area of 20-30 ha of UAA were most numerous, with the share of 24.7%.

According to the data from the Statistics Poland (GUS, 2015, 2018) it appears that the milk production in Poland is gradually increasing. In total, on the national scale, in the years 2006-2010 and 2011-2015 it averaged 11,889 and 12,433 million litres respectively, while in the following years from the three-year period 2015-2016-2017 it was 12,859, 12,867 and 13,305 million litres, respectively. The increase in the milk production was linked to the increase in the milk yield of cows. The average annual milk yield per 1 cow in the years 2006-2010 and 2011-2015 averaged, respectively, 4,357 and 5,000 litres, while in the following years from the three-year period 2015-2016-2017 it was 5,395, 5,563 and 5,687 litres, respectively.

The productivity of cows as well as the composition and quality of milk are determined by many factors that are interrelated and interact with each other, with 30% of the impact being attributed to genetic factors and 70% to non-genetic factors. Genetic factors include breed and individual factors. On the other hand, non-genetic factors include: 1) environmental factors (feeding, season, microclimate); 2) cow-related factors (size, age, physiological state, lactation phase, age at first calving, fertility, health, health of the udder); 3) human-dependent (method of keeping, method and frequency of milking, feeding technique); 4) equipment-dependent (quality and efficient of milking equipment) (Wielgosz-Groth, 2009).

The studies show that improving the genetics and method of feeding of animals may increase the milk production from 2 to 3% per cow annually (Von Keyserling, Rushen, de Passille and Weary, 2009, after: Kelm and Freeman, 2000; Fleischer, Metzner, Beyerbach, Hoedemaker and Klee, 2001). According to reports of the European Commission (2015), it is expected that the milk yield of cows will increase in the coming years (by 2025), but these changes will vary in intensity in the EU-15[1] and EU-N13[2] countries. The number of cows is likely to decrease, but this will not reduce the milk production in the EU. Just the opposite, its volume will increase due to the higher milk yield of cows.

In Poland, the natural conditions for the rearing of cattle and milk production are quite good, mainly in the central and north-eastern regions of the country, with the large percentage of meadows and pastures. According to the studies conducted by the GUS in 2016, in the general national area of meadows and permanent pastures, the area occupied for their cultivation in the Mazowieckie Voivodeship had the largest share (17.0%). The share of the area occupied for meadows and permanent pastures was smaller but also relatively large in the Podlaskie Voivodeship (12.2%), Warmińsko-Mazurskie Voivodeship (10.4%) and Lubelskie Voivodeship (7.4%). In these four voivodeships, the total area of meadows and permanent pastures occupied 47.0% of their total area in the country (GUS, 2017). The rearing of dairy cattle is very strongly linked to the use of land intended for the production of feed, in particular feed from non-commodity products (e.g. hay, hay silage). The increased availability of own feed makes the rearing of cattle and thus the milk production less vulnerable to fluctuations in the supply and prices of fodder crops.

The specialisation of farms and the related increase in the production scale are the factors conducive to the development of farms. This involves the use of specialised management techniques, the specialisation of labour and the possibility (and even the necessity) to use better machinery or equipment, which, consequently, contributes to the higher labour productivity. A positive effect of these changes is the improvement in production technology and the increase in the production capacity of assets held (e.g. the more efficient use of cowbarns, specialised machinery and equipment). In the context of economic features, the reason for conducting the commodity production is to obtain income adequate to expectations, i.e. comparable with income of other socio-professional groups. This is the farmer's primary objective, but its implementation requires proper organisation of the production process and the interaction of many factors. In this regard, the production scale is essential (Skarżyńska and Abramczuk, 2018). In the case of farms involved in the milk production, it may be measured by the number of dairy cows on the farm, the annual milk production volume or the value of milk sold.

The results of the studies show that the improvement in the income situation of farms oriented towards the milk production depends mainly on the possibility of reducing unit costs of its production. On the other hand, the analysis of the milk production costs on farms keeping agricultural accounts shows that an important factor shaping their amount is the herd size and milk yield of cows (Czakowska and Sass, 2009 after: Mańko, 2007; Ziętara, 2007).

[1] EU-15 – countries forming the EU before the accession of new members in 2004. They are: Austria, Belgium, Denmark, Finland, France, Greece, Spain, the Netherlands, Ireland, Luxembourg, Germany, Portugal, Sweden, United Kingdom, Italy.

[2] EU-N13 – countries which joined the EU in 2004 and later. These are: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia, Hungary.

The major objective of the studies was to specify the diversification in the profitability of milk production depending on the herd size on farms and to identify the major determinants of positive economic effects. What was assessed were the milk yield of cows and the price of milk sold as well as inputs and costs incurred, which imply the production intensity level, while are also strongly dependent on the farmer. The importance of cost accounting and the assessment of profitability of production on the farm results from a need to rationally use all production factors. The producer should know the benefits (or losses) caused by the specific way of their use. The economic account should be based on the rational management principle, in two options, i.e. maximum output and minimum input. The condition of rational management is the possibility of choosing how to solve the problem. In order to make a rational choice, we need to know what resources are available, what is the objective and how long it takes to achieve it. Both options of the rational management principle are equivalent and lead to the same outcome. Given the cognitive and utilitarian aspects of the studies conducted, it is necessary to stress the possibility and need to implement them into economic reality, which, just like the studies themselves, can take place at various levels of generality.

Test material and methodology

The study material was the empirical data describing the activity of livestock production dairy cows. This activity was the subject of studies conducted within the AGROKOSZTY System of Agricultural Data Collection in 2014 and 2017. Farms for the studies were selected purposively from the sample of Polish FADN, the condition was a specific size of the cow herd and the farmer's consent to conduct the studies. The selection of farms was made independently each year, in 2014 the sample consisted of 169 farms, and in 2017 – 159, they were situated across the country.

The data collected in the AGROKOSZTY system was complemented by data from the Polish FADN database and then processed in accordance with the cost accounting method developed for agricultural products (Skarżyńska and Abramczuk, 2018). Farms from the study sample were grouped according to the production scale, the criterion was the number of dairy cows in the herd[3]. Three scale ranges have been identified, i.e. small, medium and large. The limits of the scale ranges

[3] The production scale is the volume (size) of the homogeneous production on the farm. It can be determined in absolute terms, i.e. in natural measures (e.g. number of cows, number of litres of milk) or in value terms in PLN, but it also functions as a relative concept, i.e. in relation to the relevant reference unit (e.g. milk yield of a cow in litres) or compared to other scale sizes. The rationality of the production scale depends on the level of technology, production technology adopted and environmental and economic conditions. The production scale is a quantitative (technical) and organisational-economic concept, but does not include the geographical concentration of production (Fereniec, 1999).

In the studies conducted, the production scale means the size of production on farms and is associated with the potential of owned resources of manufacturing factors, as the size of production depends on their size and quality. Changes in the agrarian structure of farms are conducive to a process of specialisation involving an increase in the production scale and its concentration, while these phenomena are not identical. The concept of concentration includes the geographical proximity, which is not included in the production scale. Concentration also means, unlike the production scale, a certain process, not a condition. These changes are the result of the agricultural development and also determine its further development.

(i.e. the minimum and maximum number of cows) during the years of studies were the same or different to a small extent[4]. In order to show the changes in the results, the analysis covered the two-year averages (i.e. the average results from two years of studies, i.e. 2014 and 2017), this approach eliminates the impact of accidental fluctuations possible in the analysis of annual data (e.g. due to changes in market conditions) and allows to determine the type of change with greater certainty.

When dividing the study sample of farms into groups differing as regards the production scale, account was taken of the sample size and the distributions of the feature, which was the scale criterion (the number of dairy cows in the herd). It was assumed that the number of farms in the identified scale ranges should be as high as possible, the average level of the feature adopted as the scale criterion should be close to the median of this feature and the limits of the scale ranges should not be adjacent. These factors determined the selection of three scale ranges, as a result, the number of farms in the identified ranges does not cover the entire study sample.

It should be noted that the size of the production scale ranges is relative, this means that the scale size adopted as large can be considered small on farms where organisation of production is different. Nevertheless, the results of the studies are an important rationale for selecting the scale size, which may guarantee the relatively high efficiency of production conducted.

The results of the studies were presented in the tabular system, using the horizontal analysing comparing the parameters describing the analysed activity on farms with the small, medium and large production scale. The studies included revenues, i.e. the value of potentially commodity production, costs and economic effects. The basic measure for the assessment of the effects achieved was the level of income from activity without subsidies and income from management activity without subsidies. The method of calculating these categories has been presented below:

income from activity without subsidies = production value – total costs (direct + indirect),

income from management activity without subsidies = production value – economic costs (Economic Indicators..., 1994; Samuelson and Nordhaus, 1995),

or

income from management activity without subsidies = income for activity without subsidies – cost of own production factors.

The results of the studies were provided per 1 dairy cow. The production value includes milk (main product), the value of the cow culled according to the programme resulting from the production life of animals (by-product) and livestock growth, i.e. calves after weaning from the cow. The costs were analysed as divided into direct and indirect. Direct costs are components that can be undoubtedly attributed to a given activity, their size is proportionally related to the production scale

[4] Milk production scale ranges (i.e. small, medium, large), the selection criterion was the number of cows on the farm: in 2014 – 5-15, 20-45, 50-100 head, in 2017 – 5-15, 25-45, 55-140 head.

and they have a direct impact on the production size (volume and value). On the other hand, indirect costs are common to the whole farm, they have been distributed among the activities carried out according to the share of the production value of each of this activity in the total production value.

The costs of own manufacturing factors, i.e. labour, land and capital, are treated as opportunity costs, they are measured by the value of the best missed opportunity. It is assumed that individual goods could be used in other ways, which could generate higher income. For the purposes of the analysis, own labour has been valued at the normative rate, determined based on the average, in a given year, remuneration for workers employed throughout the national economy, assuming that one full-time worker works in agriculture for 2,120 hours a year. This calculated payment for 1 hour in 2014 was PLN 14.29, and in 2017 it was PLN 16.14[5]. The measure of the cost of land was lease rent, the cost of renting the area occupied for the production of own feed from non-commodity products has been estimated. The algorithm used shall take into account the type and class of land and the tax district according to the rules applicable to the calculation of agricultural tax. This approach means that the amount of the estimated cost of land, in addition to the soil quality class, is highly determined by the regional location of farms included in the study sample. Lease rent is expressed in dt of wheat, its amount has been determined according to the average wheat buying-in price in the country (in 2014 – PLN 68.36/dt, in 2017 – PLN 66.44/dt). The cost of operating capital was the value of inputs incurred on working production means – basic and auxiliary.

The first group includes those that are consumed in one production cycle and transfer their whole to a newly produced product, while the other group includes these means that are not part of a new product, but are necessary in the production process (Encyclopaedia..., 1984). The account includes, inter alia, seeds, fertilisers, feed, medicines and veterinary products, animals introduced into the herd as part of its restocking, fuel, materials for ongoing renovations of buildings and machinery and the value of production services. The cost has been estimated at the interest rate for current account deposits, the average interest rate has been adopted after the GUS, in major commercial banks (0.80% in 2014 and 0.60% in 2017). It was assumed that working capital was frozen for 3 months. The cost of using fixed capital is the cost of capital invested in own productive fixed assets, i.e. buildings and structures, machinery, technical equipment, motor vehicles and other means of transport. They can be used repeatedly in production processes and are consumed gradually for many years, transferring their value to manufactured products. The cost of fixed capital has been estimated at the interest rate for deposits deposited for 1 year, at the average interest rate in major commercial banks, according to the GUS (2.40% in 2014 and 1.50% in 2017). Where a farmer uses his savings to pay for production means, there is an economic cost due to the use of the owner's capital. It was therefore calculated how much the farmer potentially lost by buying production means rather than depositing that money into a bank account.

[5] Own calculations based on the CSO data.

To assess the effectiveness of using of inputs incurred and the economic purposefulness of intensifying the production, marginal accounting was carried out. Marginal costs have been calculated, being a measure of the total cost response to the increase in the production volume by unit. The marginal cost may change with the next unit produced or may remain unchanged. As long as the marginal cost is lower than the unit (average) cost, it results in a decrease in the unit cost. However, if the marginal cost exceeds the average unit cost, then it stimulates its increase (Samuelson and Nordhaus, 1995). In calculating the marginal cost, an assumption was made on the invariability (ceteris paribus) of other factors affecting the level of costs. In the studies, the basis for calculating the marginal and unit (average) costs was the average results for the identified production scale ranges.

Depending on the scale and inputs of production means, the limit of production intensity will vary. Its level is determined by the following relationship:

$$\Delta K\text{, PLN (increase in costs)} / \Delta P\text{, PLN (increase in the production)} \leq 1$$

This means that the amount of incurred inputs and costs will be justified, when the determined intensity limit is less than or equal to 1.

The measure for the assessment of the economic efficiency of milk production was the profitability index, which has been designated as I and II according to the cost group included in the denominator. This indicator informs about the percentage in which the production value expressed in current prices covers the costs incurred for its production. The profitability index I – reflects the surplus of the production value over the total costs, while the profitability index II – the surplus of the production value over the economic costs.

Selected information on farms where the studies were conducted

The total, in the study years, number of farms in the identified groups according to the scale criterion adopted accounted for 73.8% of the total study sample. This is due to the fact that the limits of the scale ranges were not tangential. In the analysed set of farms, the largest share was that of entities with the average production scale, representing 34.5%. Other positions were taken by small- and large-scale milk production farms, their share was 26.2 and 13.1%, respectively – Table 1.

Table 1

Selected information on groups of farms keeping dairy cows on average in the study years (i.e. in 2014 and 2017)

Specification		On average in the study sample	Production scale[a], number of cows/farm		
			Small	Medium	Large
Number of farms in the studies		328	86	113	43
Utilised agricultural area (UAA)	(ha)	47.82	24.41	49.99	103.42
Area of permanent grassland (PG)	(ha)	14.99	6.80	16.79	32.61
Fodder area per 1 cow	(ha)	0.54	0.59	0.60	0.49
Stocking density of cows per 100 ha of UAA	(head)	62.2	37.5	61.5	70.0
Milk yield of cows	(litre)	6225	4679	5956	6760
Annual average number of dairy cows	(head)	29.8	9.2	30.8	72.4
Culling rate of dairy cows	(%)	15.8	14.3	16.4	18.1
Total labour inputs per 1 cow	(hours)	89.6	187.5	90.6	57.7
Including own labour inputs		82.6	185.9	85.5	46.2
Share of the production value generated by dairy cows in the total production of the farm	(%)	69.7	44.9	68.9	76.6

[a] Production scale – small, medium, large, respectively, in the ranges in 2014 – 5-15, 20-45, 50-100 cows, and in 2017 – 5-15, 25-45, 55-140 cows.

Explanations: Fodder area – area for the production of own feed from non-commodity products. This feed is made on the farm for feeding animals, has no alternative way of management in a commodity form.
Labour inputs – inputs incurred on handling livestock and production of own feed from non-commodity products.

Source: own calculations based on data from the AGROKOSZTY system and Polish FADN.

On average, in the study sample, the utilised agricultural area (UAA) was 47.82 ha and permanent grassland (PG) was 14.99 ha. In the groups of farms, as the number of cows in the herd increases, the UAA and PG areas are clearly increasing gradually. The livestock production is closely linked to the crop production and, in the case of dairy cows, it is dependent on the availability of permanent grassland. On average, in the sample the share of PG in UAA was 31.3% and in the groups of farms it was within the range of 27.9-33.6%.

The results of the studies presented in Table 1 indicate a relationship between the size of cow herds and their milk yield. When comparing medium-scale milk production farms to those with the small-scale milk production, the difference in favour of the first group was 1,277 litres, and when comparing the scale large to the medium scale – 804 litres. However, between the extreme scale ranges, the difference in the milk yield of cows was 2,081 litres. It is estimated that the milk production technology (understood in a broader context[6]) used on farms keeping relatively large cow herds led to an increase in their milk yield. In this context, attention should be paid to the period of production use of cows. The culling rate was increasing as the milk yield increased, which means that high-performance cows were used for a shorter period of time. On small-scale milk production farms, this rate was 14.3%, on the medium scale – 16.4%, and on the large scale – 18.1%.

The stocking density of dairy cows per 100 ha of UAA evidences the importance of this production type and thus the specialisation of farms. Comparing the extreme scale ranges, i.e. large to small, the stocking density of cows was by 32.5 head larger (i.e. 86.7%). This situation is reflected in the share of production value generated by dairy cows in the structure of the farm's production value. This share was largest (76.6%) on farms keeping large cow herds (the limit scale range is 50-140 head) with the relatively high milk yield (6,760 litres). Compared to medium-scale milk production farms (the limit scale range is 20-45 cows) was higher by 7.7 pp on the small scale (the limit scale range is 5-15 cows) by 31.7 pp.

The labour intensity of the production is also important. The increase in the size of cow herds was conducive to the decrease in labour inputs incurred on handling cows. This means that labour force was used more efficiently. Also, the share of own labour in total inputs was decreasing, for the small scale it was 99.1%, medium – 94.4% and large – 80.1%.

Costs of keeping cows and milk production income

The analysis of the data contained in Table 2 shows that as the number of cows increased, their milk yield and the price of milk increased. However, the differences resulting from comparing the results obtained on average in the group of medium-scale milk production farms to the small scale were higher than when referring the results of the large scale to the medium scale. By contrast, when comparing the extreme scale ranges, in favour of the large scale – the milk yield of cows was higher by 44.5% (i.e. by 2,081 litres) and the price of milk by 16.3% (i.e. by PLN 0.20).

The share of milk in the total production value per 1 cow (i.e. in revenues) was within the range of 86.0-91.3%. The remaining components of the production value are calves after weaning from the cow and the culled dairy cow. The analyses showed that the total cost of keeping dairy cows rose as the production scale increased. This was determined by both direct and indirect costs.

[6] Livestock production technologies may be defined as animal keeping systems related to feed production and animal feeding methods, with the herd size and herd management method, method of keeping animals, administration of feed and removal of faeces as well as the milking method and animal reproduction method (Brzóska, 2009).

Table 2

Costs and economic results from the milk production depending on the production scale on average in the study years (i.e. in 2014 and 2017)

Specification		On average in the study sample	Production scale, number of cows/farm		
			Small	Medium	Large
Milk yield of cows	litre	6 225	4 679	5 956	6 760
Milk selling price	PLN/litre	1,40	1,23	1,39	1,43
		Per 1 dairy cow, PLN			
Total production value (PV)		9 577	6 726	9 176	10 563
Incl.: milk		8 676	5 786	8 268	9 639
Direct costs		3 416	2 646	3 426	3 535
Incl.: Herd replacement		588	522	582	714
Feed in total		2 427	1 847	2 428	2 400
Veterinary treatment and services		258	185	275	255
Gross margin without subsidies		6 162	4 081	5 750	7 028
Actual indirect costs		1 540	1 343	1 473	1 648
Gross value added from activity		4 622	2 738	4 278	5 381
Depreciation		1 103	996	1 115	1 152
Net value added from activity		3 519	1 742	3 163	4 228
Cost of external factors		437	235	369	545
Income from activity without subsidies		3 082	1 507	2 794	3 683
Total costs (TC)		6 496	5 219	6 382	6 879
		Economic efficiency indices			
Share of the cost of purchased feed in the total costs of feed	(%)	60.2	32.0	54.9	68.0
Share of the total cost of feed in the price of milk	(%)	28.0	32.1	29.3	24.8
Share of total costs of producing 1 litre of milk in its selling price	(%)	74.8	90.7	77.1	71.2
Total costs per 1 PLN of income from activity without subsidies	(PLN)	2.11	3.46	2.28	1.87
Income from activity without subsidies per 1 litre of milk	(PLN)	0.50	0.32	0.47	0.54
Profitability index I (PV/TC)	(%)	147.4	128.9	143.8	153.5

Source: own calculations based on data from the AGROKOSZTY system and the Polish FADN.

The structure of total costs was dominated by direct costs, their share, on average, in the identified groups of farms (production scale ranges) was between 50.7 and 53.7%. The component of direct costs that determined their rise in the subsequent scale ranges was the cost of feed. The level of total costs of feed on small-scale milk production farms were quite strongly influenced by own commodity feed (accounting for 52.6% in the structure of total costs of feed) and for the production on the medium and large scale – purchased feed (accounting for, respectively, 54.9 and 68.0% in the structure). When comparing large-scale milk production farms to the small scale, the cost of feed per 1 cow differed by PLN 553 (i.e. by 29.9%). This difference was determined by the higher share of purchased feed in the feed ration for cows (by 36%). Regardless of the cost of feed, the higher milk yield of cows on farms keeping large cow herds – when compared to those with small herds – entailed the higher costs of herd replacement (by 36.8%) and treatment of animals (by 37.8%). The studies by Wielgosz-Groth (2009) show that feeding cows has a major impact on the milk yield of cows. The high milk yield, however, is often accompanied by negative phenomena, which include, *inter alia*, the occurrence of metabolic diseases and infertility, and consequently the higher culling rate and shortening of longevity of cows (Bogucki, Sawa and Neja, 2007; Gil, Felenczak, Żychlińska-Buczek and Siatka, 2007; Runowski, 2007).

The results of the analysis show that as the number of cows in the herd increases, indirect costs of keeping them are rising. This direction of change concerned three groups of costs as components of this aggregate, i.e. actual indirect costs, depreciation of fixed assets involved and costs of external factors. The level of actual indirect costs was most influenced by the cost of fuel, the cost of renovation of buildings and machinery and the cost of production services. The growing burden with the cost of fuel is linked to the involvement of transport means in the handling of cows, but mainly in the production of own feed from non-commodity products (e.g. silage, hay silage). The increased milk production scale is also strongly related to equipping cowbarns with specialised machinery and equipment for administering feed and milking, but also to the level of mechanisation of work related to the removal of manure from livestock buildings. The consequence is the growing burden of 1 head with the cost of depreciation of these fixed assets. The higher production scale also determined the greater share of paid labour in total inputs and thus its higher cost.

The total costs, i.e. direct and indirect costs in total, of keeping 1 cow were rising in the subsequent groups of farms, i.e. as the number of cows in the herd increased. When comparing the medium scale to the small scale, they were higher by 22.3% (by PLN 1,163) and the large scale to the medium scale – by 7.8% (by PLN 497). This means that the total cost rise for the medium scale was by 14.5 pp stronger than for the large scale. In both groups of farms, the revenue growth was stronger than the cost rise, for the medium scale by 14.1 pp and for the large scale – by 7.3 pp. This resulted in the gradual income growth.

Income without subsidies per 1 dairy cow increased with the increase in the milk production scale, for the small scale it was PLN 1,507, for the medium scale – PLN 2,794 and for the large scale – PLN 3,683. This means that the level of this income for the medium scale in relation to the small scale increased by 85.4% and for the large scale in relation to the medium scale – by 31.8%. On the other hand, when comparing the extreme scale ranges, income increased in favour of the large scale by 144.4% – Table 2.

Income without subsidies is a category suitable for assessing the results of a given activity in the longer term, but assuming that the farm's production capacity is maintained at a stable level. This income is an economic surplus left for paying the labour inputs incurred by the farmer and his family and to pay own capital involved.

In order to assess, depending on the milk production scale, the effectiveness of using the inputs incurred, the marginal cost of producing an additional production unit has been calculated. The basis for calculating the marginal costs and the average unit costs was the average results at the level of total costs obtained in the identified ranges of the production scale. The medium scale has been compared with the small scale and the large scale was compared with the medium scale – Table 3.

The results of the study showed that for the medium scale, the marginal cost (PLN 1.06) was by 0.9% lower than the average unit cost (PLN 1.07) so it put pressure on its decrease, which is a beneficial phenomenon. This means that the scale growth was reasonable. The milk production on farms keeping large cow herds was more favourable. The marginal cost of producing 1 litre of milk was PLN 0.98 and was by 3.9% lower than the average unit cost (PLN 1.02). Thus, the marginal cost resulted in the decrease in the average cost. However, it should be noted that for both the medium and large scale, the marginal cost was lower than the limit cost, i.e. the selling price of milk, nor was the limit of production intensity exceeded. This means that the costs increased more slowly than the production value. Its increase by PLN 1 required the rise in the costs for the medium scale by PLN 0.68 and for the large scale – by PLN 0.62.

Table 3

Unit costs of milk production depending on the production scale on average in the study years (i.e. in 2014 and 2017)

Specification		Production scale, number of cows/farm		
		Small	Medium	Large
Marginal cost	(PLN/litre)	-	1.06	0.98
Average unit cost	(PLN/litre)	1.12	1.07	1.02
Limit cost (price)	(PLN/litre)	1.23	1.39	1.43
Intensity limit ($\Delta K/\Delta P$)	(PLN)	-	0.68	0.62

Source: study based on own studies.

The highest cost of production of 1 litre of milk (PLN 1.12) was recorded on farms keeping small cow herds with the relatively low milk yield (4,679 litres). When compared to the lowest level of this cost (PLN 1.02) in entities with large herds of high-performance cows (6,760 litres) it was higher by 9.8%. However, in each scale range, the unit cost of the milk production was lower than the selling price. For the small production scale, it accounted for 90.7% in the price of milk, while for the medium scale – 77.1% and for the large scale – 71.2%, the positive effect of the production scale is clearly visible. The advantage of the large scale is also indicated by the cost of generating income of PLN 1 from activity without subsidies, which was PLN 1.87 and when compared to the small scale (PLN 3.46) it was lower by 46.0%. On the other hand, income from activity without subsidies per 1 litre of milk for the large scale was the highest – it was PLN 0.54 and was higher than the level of the small scale (PLN 0.32) by 68.8%.

The production scale is also a factor clearly differentiating the economic effectiveness of the milk production, which is reflected by the profitability index I (the ratio of the production value to the direct and indirect costs in total). Its value expresses the influence of internal factors, i.e. those to some extent dependent on the farmer, and of external factors, i.e. independent factors. This applies to the intensity of the technology used, prices of production means, milk yield of cows and the selling price of milk. The value of the profitability index indicates how many times the funds involved as costs in the production process have been multiplied. The results of the calculations show that the large-scale milk production was characterised by the highest economic effectiveness. The profitability index I was 153.5% and was by 9.7 pp higher when compared to the medium scale and by 24.6 pp higher when compared to the small scale – Table 2.

Feed structure and consumption

The results of the analysis of the consumption structure for concentrate feed in the identified groups of food indicate the different share of purchased concentrate feed and own feed in the feed ration for cows (Table 4). The increase in the number of cows in the herd, and at the same time their higher milk yield were associated with the greater share of purchased concentrate feed. By comparing the large scale to the small scale, this share was higher by 42.1 pp (the share of own feed was also by 42.1 pp lower). Concentrates and industrial mixtures were dominant in the structure of purchased feed on medium- and large-scale milk production farms, their share was, respectively, 58.7 and 51.7%, while for the small production scale it was 46.7%.

Table 4

Consumption structure and consumption of feed per 1,000 litres of milk in the groups of farms, on average, in the study years (i.e. in 2014 and 2017)

Specification		On average in the study sample	Production scale, number of cows/farm		
			Small	Medium	Large
Concentrate feed	(%)	100.0	100.0	100.0	100.0
Including: purchased		52.1	21.5	44.2	63.6
own		47.9	78.5	55.8	36.4
Feed from non-commodity products	(%)	100.0	100.0	100.0	100.0
Including: Root crops		0.1	0.1	0.1	0.0
Hay and straw		7.3	15.9	8.1	5.4
Green forage		24.0	31.4	24.7	24.4
Silage and hay silage		68.6	52.6	67.1	70.2
Consumption of feed per 1,000 litres of milk					
Concentrate	(dt)	2.98	3.49	3.12	2.65
Root crops	(dt)	0.02	0.04	0.02	0.00
Hay and straw	(dt)	1.62	4.27	2.04	1.05
Green forage	(dt)	5.32	8.42	6.18	4.71
Silage and hay silage	(dt)	15.21	14.13	16.76	13.56

Source: own calculations based on the data from the AGROKOSZTY system.

In feeding dairy cows, the importance of roughage is just as important as that of concentrate feed. The characteristics of this feed complement each other. The analysis of the consumption structure of feed from non-commodity products shows that the increase in the milk yield of cows was associated with the higher share of silage and hay silage in the feed ration for cows. When comparing the results of the large scale to those of the small scale, their share was higher by 17.6 pp, with the smaller share of green forage (by 7.0 pp) and hay and straw (by 10.5 pp). The share of root crop feed in feeding cows was marginal, and in large-scale milk production entities, this feed was completely eliminated from the feed ration.

It may be presumed that on large-scale milk production farms the properly balanced feed ration provided the animals with the necessary nutrients that met both living and production needs. Concentrate feed used as a complement to good quality roughage stimulated the growth in the milk yield of cows. As a result, in this group of farms the consumption of concentrate feed per 1,000 litres of milk was the smallest and amounted to 265 kg. When compared to the medium scale, it was lower by 15.1% (i.e. by 47 kg) and to the small scale by 24.1% (i.e. by 84 kg).

The consumption of feed per 1,000 litres of milk determines the effectiveness of feeding cows. The figures in Table 4 show that on farms keeping very numerous cow herds and at the same time with the high milk yield (6,760 litres), the feeding system was the most effective. The consumption of feed from all groups was the smallest, while for the milk production on the medium and small scale it was much higher.

The results of the studies conducted by other authors show that keeping high-performance cows is more profitable than keeping cows with worse genetic potential, even though it entails higher costs of cereal meals, concentrate feed and roughage. In addition, in order to fully use the production potential of these animals, the feed ration should contain good quality feed in the appropriate quantities (Krpalkova, Cabrera, Kvapilik and Burdych, 2016).

Technical effectiveness of milk production

The technical effectiveness should be understood as a result of a specific system on the farm. Its efficiency is determined by the quantity and quality of the production factors used, properly selected manufacturing technology (i.e. proportions of inputs incurred) and the ability to manage the farm understood as the ability to control the process of transformation of inputs into the final product. Within a long period of time, this system is not static, it can be modified and improved under the influence of various information (Kagan, 2010).

The effectiveness of milk production is determined by many factors. On the one hand, we are dealing with genetic conditions of animals, and on the other – with factors dependent on the production technology, but also on the environment. The studies conducted assessed the technical effectiveness of milk production calculated as the productivity of land, labour and involved production means – Table 5.

Table 5

Indices of technical effectiveness of milk production in the groups of farms, on average in the study years (i.e. in 2014 and 2017), in litres per 1 cow

Specification	On average in the study sample	Production scale, number of cows/farm		
		Small	Medium	Large
Milk production per 1 ha of fodder area	11 527	7 997	10 010	13 937
Milk production per 1 hour of labour in total	70	25	66	117
Milk production per PLN 100 of depreciated fixed assets	565	470	534	587
Milk production from concentrate feed	3 709	3 267	3 718	3 579
Milk production from roughage	2 515	1 411	2 238	3 180

Source: own calculations based on data from the AGROKOSZTY system and the Polish FADN.

The yield (production) of milk from 1 ha of fodder area on farm with the large--scale production exceeded the medium scale by 39.2% and the small scale by 74.3%. In the case of the labour productivity, the differences between the groups of farms were larger, when comparing the large scale to the small scale as much as 4.7 times. The labour productivity for the small-scale milk production was 25 l of milk per 1 hour of labour in total, while for the large scale it was 117 l of milk. It was determined mostly by the milk yield of cows, but also by the labour intensity of production. The productivity of fixed assets was characterised by the lowest scale of differentiation, but the relation with the milk yield of cows is visible. Its higher level was a reason for which on large-scale milk production farms the productivity of fixed assets was the highest, even though the cost of depreciation of assets involved was also the highest. The difference in the productivity of fixed assets between the extreme groups of farms was not large – only 1.2-fold. Given that the milk yield of cows was differentiated 1.4 times, this evidences the higher burden with fixed assets of farms keeping large cow herds.

The technical effectiveness indicator is also the milk production from roughage, calculated as a difference between the total productivity and the milk production from concentrate feed, assuming that from 1 kg of feed we obtain 2 kg of milk (Ziętara, 2007). On farms keeping large herds of relatively high-performance cows (6,760 litres), the largest milk production from roughage was obtained – 3,180 litres/cow. This level of production was associated with the relatively low consumption milk of roughage per 1 litre of milk – 0.265 kg. By contrast, on farms keeping small cow herds with the low milk yield (4,679 litres), the milk production from roughage was the smallest, amounting to 1,411 litres/cow. At the same time, the consumption of concentrate feed per 1 litre of milk was higher by 31.7% amounting to 0,349 kg – Tables 4 and 5.

In the context of the results obtained, it should be noted that the milk production from roughage is highly influenced by the nutritive value of this feed. The quality differences in roughage may result from the selection of crop species, the date of harvesting of fodder material and preservation technology[7]. As reported by the literature of the subject, the risk of developing metabolic diseases of cows (due to feeding them with the higher amount of concentrate feed) is also increasing when feeding them with poor quality roughage, in addition to the lower milk production. With the increasing requirements of cows resulting from advanced genetic progress, roughage must be of high quality, only when it is the main factor allowing to achieve the high milk yield (Pawłowska, 2015).

Economic costs and income from management activity

In agriculture, just like in any other economic activity, the production process is based on the co-existence of the labour, land and capital factors. In the case of agricultural production activities, the category that reflects the coverage of production costs (direct and indirect), but also the coverage of the opportunity cost of own production factors[8] is income from management activity without subsidies. It is an economic category cleared from full production costs, which in the litreature are referred to as economic costs (Economic Indicators..., 1992; Samuelson and Nordhaus, 1995).

The category of income from management activity at the farm level is defined as the entrepreneur's profit. The entrepreneur's profit category has been presented in the income classification system according to Z. Kierul, quoted by W. Ziętara (1998). It is also strongly emphasised in economic accounts for farms in the European Union (Steinhauser, Langbehn and Peters, 1992; Kokler, Holzmann and Lobbe, 1998).

The analysis shows that the most favourable economic results from the milk production were achieved on farms keeping large cow herds. The production value allowed to fully cover the (direct and indirect) costs of keeping cows, provided payment for production factors involved (labour, land and capital) and allowed to obtain income from management activity without subsidies amounting to PLN 2,708/cow. This was contributed to by the highest, among the analysed groups of farms, milk yield of cows and the highest selling price of milk. The selling price of 1 litre of milk (PLN 1.43) obtained by producers was by 23.3% higher than the economic costs of producing 1 litre of milk (PLN 1.16/litre) – Table 6.

[7] Poor quality maize silage (about 35 kg) allows to produce 13 kg of milk while with its very good quality we can obtain 22 kg of milk. In the first case, in order to produce 22 kg of milk, it is necessary to add concentrate feed which will be an additional cost (Pawłowska, 2015).

[8] The opportunity cost is the value of the best unselected alternative. It is assumed that the individual goods could have been used in a different way which could have brought a better benefit (income). This type of opportunity costs in monetary terms is often referred to as implicit costs (i.e. impled costs), as opposed to recorded, or actually incurred, expenses referred to as explicit costs (Milewski (ed.), 2008).

Table 6

Economic costs and income from management activity in the groups of farms, on average in the study years (i.e. in 2014 and 2017), in PLN per 1 cow

Specification		On average in the study sample	Production scale, number of cows/farm		
			Small	Medium	Large
Income from activity without subsidies		3082	1507	2794	3683
Cost of own labour		1245	2825	1292	692
Income from capital and management activity without subsidies		1837	-1318	1502	2991
Cost of land		66	62	76	54
Cost of operating and fixed capital		203	135	200	229
Income from management activity without subsidies		1568	-1515	1226	2708
Cost of own production factors in total		1514	3022	1567	975
Economic costs in total (EC)		8009	8241	7949	7855
Share of the cost of own production factors in economic costs	(%)	18.9	36.7	19.7	12.4
Cost of own production factors per 1 litre of milk	(PLN)	0.24	0.65	0.26	0.14
Economic costs per 1 litre of milk	(PLN)	1.29	1.76	1.33	1.16
Profitability index II (PV/EC)	(%)	119.6	81.6	115.4	134.5

Source: own calculations based on data from the AGROKOSZTY system and the Polish FADN.

The results of the medium-scale milk production were also quite favourable. The economic costs have been fully covered and the realised price of milk (PLN 1.39/litre) was by 4.5% higher than the price which provided the full coverage of the economic costs (PLN 1.33/litre). Producers obtained income from management activities without subsidies amounting to PLN 1,226 per cow. When compared to the large-scale production, the level of this income was lower by 54.7%.

The economic results of small-scale milk producers were the poorest. The production value per 1 cow provided the coverage of direct and indirect costs of keeping cows, while the estimated cost of own labour was paid at the level of only 53.3%. Therefore, the estimated cost of land, operating and fixed capital involved has not been covered. Farmers did not obtain income from management, it was a negative value. This means that the production value covered the economic costs below the profitability threshold. In order to fully cover the economic costs, it would be necessary to increase the selling price of milk or increase the milk yield by more than 43% (the price should be PLN 1.76/litre or the milk yield of cows – 6,700 litres).

Income from management is one of the criteria for assessing organisation and management of the farm. The results of the analysis show that, on average, in the study sample of milk production farms, as well as on farms with the medium- and large-scale milk production, income from management has been realised. On the other hand, in the small-scale milk production, this income was negative.

According to the figures contained in Table 6, the share of costs of own production factors in economic costs in total was decreasing as the scale increased. In the structure of costs of production factors, the cost of own labour was the largest, which also decreased as the scale increased. It should be added that the level of this cost was directly related to the labour intensity of production, and this intensity was the largest on farms with the low milk-yield of cows, and thus with the small headage. The second place in the structure of costs of production factors was occupied by the cost of capital, its share was increasing as the milk production scale increased. The smallest share was characteristic of the cost of land, which was changing in various directions in the analysed groups of farms.

There are strict relationships between the production value, costs incurred and the economic results achieved. As a measure for assessing the economic effectiveness of production in the groups of farms differing as regards the scale, the profitability index II was used – expressed as a percentage ratio of the production value to economic costs. For the small-scale milk production, this index did not exceed the profitability threshold and amounted to 81.6%. By contrast, on medium-scale milk production farms, it reached 115.4% and on a large scale it reached 134.5%. The positive impact of the scale of milk production on its cost-effectiveness is clearly evident.

Final comments and conclusions

The studies on the impact of the production scale on the profitability of cow's milk production was conducted based on the averaged results from two study years, i.e. 2014 and 2017. Farms for studies were selected purposively. The criteria for their selection in both years were the same, and the size of the study sample was also similar. The two-year averages have been analysed, this approach eliminates the impact of random fluctuations possible in the analysis of annual data on the results. The results achieved present the profitability of milk production in the groups of farms differing in terms of the production scale. The measure of the scale size was the number of cows in the herd. The following conclusions can be drawn on the basis of the analysis carried out:

- As the size of the cow herd increased, their milk yield and the price of milk increased, as a result the revenues (production value) increased. The production value per 1 cow for the large scale exceeded the level of the small scale by 57.0% and of the medium scale by 15.1%. On the other hand, the cost of keeping 1 cow for the large scale, when compared to the small scale, rose by 31.8% and to the medium scale – by 7.8%. The stronger growth of revenues rather than costs provided the gradual (as the scale increased) rise in income. Income without subsidies per 1 dairy cow in the small-scale milk production was PLN 1,507, for the medium scale it was PLN 2,794 and for the large scale – PLN 3,683. By contrast, the profitability index (revenue-to-cost ratio) which illustrates the economic effectiveness of milk production in the subsequent scale ranges was 128.9, 143.8 and 153.5%.

- The structure of total costs of keeping cows was dominated by direct costs, and their share in the identified scale ranges was between 50.7 and 53.7%. The rise in direct costs determined the cost of feed. Its amount for the small-scale milk production was highly influenced by own feed and for the medium and large scale – by purchased feed. The higher number of cows in the herd also stimulated the rise in indirect costs. This is related to, inter alia, equipping cowbarns with specialised equipment and the higher level of employment of paid workers.
- On farms keeping numerous cow herds (large scale), the feeding system was the most effective, the consumption of concentrate feed per 1,000 litres of milk was 265 kg. When compared to the medium scale, it was lower by 15.1% (i.e. by 47 kg) and to the small scale – by 24.1% (i.e. by 84 kg). It is estimated that concentrate feed was used as a complement to good quality roughage. The total consumption of green forage, silage and hay silage for the large-scale milk production was 18.27 dt and when compared to the medium scale was lower by 4.67 dt and to the medium scale – by 4.28 dt. The consumption of hay and straw was also the lowest for the large-scale milk production.
- The milk productivity from 1 ha of fodder area illustrates the technical effectiveness of its production. On large-scale farms, this productivity exceeded the level of the medium scale by 39.2% (3,927 litres) and of the small scale by 74.3% (5,940 litres). The same direction of change was also demonstrated by the milk production from roughage, which was the largest on farms keeping large cow herds. When compared to the medium scale, it was higher by 42.1% (942 litres) and to the small scale – by 125.4% (1,769 litres).
- The burden on the milk production with the cost of own manufacturing factors involved was the lowest (PLN 975/cow) on farms keeping large herds of high-performance cows. When compared to the medium scale, it was lower by 37.8% and to the small scale – by 67.7%. The cost of own production factors per 1 litre of milk stimulated the decrease in economic costs. As a result, their amount per 1 litre of milk for the large scale (PLN 1.16), in relation to the medium scale was lower by 12.8% and to the small scale – by 34.1%. The profitability index, understood as s surplus of the production value over economic costs, did not exceed the profitability threshold for the small-scale milk production, standing at 81.6%, while for the medium scale it reached the level of 115.4% and for the large scale – 134.5%.

The results of the studies allow for a conclusion that the milk production's economic effectiveness is determined by various factors. On the one hand, it depends on the number and genetic potential of animals, and on the other hand, on the technical effectiveness of their feeding and the environmental conditions. Increasing the production scale brings benefits in a form of better production results, decreasing unit costs and generating higher income from the production unit. This is somehow influenced by the fact that as the production scale increases, the farmer's management skills increase, this is often reflected in income from management.

The higher milk production scale stimulates its greater profitability, but also entails the higher demand for agricultural land, which can sometimes be a barrier to the development of this type of production. In the case of rearing dairy cows (and other ruminants), roughage (green forage, silage, hay) is necessary, which most often needs to be produced on farms, as its availability in the market is low or even none. Another issue that obliges farmers to provide certain land is a need to manage organic fertilisers (manure, slurry) in a way that does not cause the environmental pollution (Regulation..., 2018).

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WPŁYW WIELKOŚCI SKALI NA OPŁACALNOŚĆ PRODUKCJI MLEKA KROWIEGO

Abstrakt

Tematyka opłacalności produkcji rolnej jest często poruszana w ramach zagadnień ekonomiki rolnictwa. W opracowaniu pokazano zróżnicowanie opłacalności produkcji mleka w zależności od wielkości stada krów oraz zidentyfikowano główne czynniki determinujące korzystne wyniki ekonomiczne. Badania przeprowadzono w gospodarstwach towarowych, które pogrupowano według skali produkcji, kryterium skali była liczba krów mlecznych w stadzie. Wydzielono trzy przedziały skali, tzn. małą, średnią i dużą. Do analizy wykorzystano dane z 2014 i 2017 roku. Zbadano efektywność żywienia krów w wydzielonych grupach gospodarstw oraz techniczną i ekonomiczną efektywność produkcji mleka. Ocenie poddano pełne koszty produkcji mleka (tj. koszty ekonomiczne) oraz obliczono dochód z działalności z tytułu zarządzania.

Wyniki analiz pokazują, że wraz ze wzrostem liczby krów w stadzie zwiększała się ich mleczność i cena mleka. Gospodarstwa charakteryzujące się dużą liczbą krów w stadzie ponosiły najniższe pełne koszty produkcji mleka, a jednocześnie uzyskały najwyższy dochód z tytułu zarządzania liczony na 1 krowę oraz na 1 litr mleka. Miarą oceny ekonomicznej efektywności produkcji mleka był wskaźnik opłacalności (relacja przychodów do kosztów ekonomicznych), najwyższy odnotowano przy produkcji mleka na dużą skalę, przy małej skali wskaźnik ten nie przekroczył progu opłacalności.

Słowa kluczowe: opłacalność produkcji mleka, skala produkcji, koszty jednostkowe.

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