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# Comparison of results coming from automatic milking system in selected countries in Europe and U.S.

# Porównanie wyników pochodzących z automatycznego systemu doju w wybranych krajach Europy i USA

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## ABSTRACT

The purpose of the study was to compare data recorded by the automatic milking in the Czech Republic, France, Germany, Italy, Latvia, Lithuania, Netherlands, Poland and the US in 2014-2017, which included the average number of robots per herd (n), the number of cows per robot (n), the daily milk yield per robot (kg), the daily milking frequency (n), the daily number of refusals (n), the milking speed (kg/min). A two- factor analysis of variance indicated a highly significant impact of the country and the country × milking year interaction on all of the controlled features related to automatic milking. The study indicated that, among others, most milk yield per robot was obtained from the robot in the US and then in Italy. In these countries, the highest milking speed was recorded, respectively: 2.74 and 2.79 kg/min, or the daily number of milkings, respectively: 2.79 and 2.74. The lowest values of the discussed features were observed in Lithuania and in Latvia. Furthermore, it was observed that, in 2014- 2017, the number of robots per farm was increased, together with the daily milk yield per robot and per cow, the number of milkings a day and the milking speed. The proven, statistical differences between the levels of milking parameters in the studied countries can probably result from the differentiated genetic potential of the milked cows and the diversity of the fodder base.

**Keywords:** automatic milking system, milking parameters, dairy cattle

## STRESZCZENIE

Celem niniejszych badań było porównanie wybranych parametrów doju zarejestrowanych przez automatyczny system doju w Czechach, Francji, Niemczech, Włoszech, Łotwie, Litwie, Holandii, Polsce oraz w Stanach Zjednoczonych (USA) w latach 2014-2017. Przeprowadzona dwuczynnikowa analiza wariancji wykazała wysoko istotny wpływ kraju oraz interakcji kraj x rok doju na wszystkie kontrolowane cechy związane z dojem automatycznym. Badania wskazały, że najwięcej mleka z robota pozyskiwano w USA oraz we Włoszech. W tych krajach odnotowano też najwyższą szybkość oddawania mleka (odpowiednio 2,74 oraz 2,79 kg/min) oraz dobową liczbę dojów (odpowiednio 2,79 i 2,74). Ponadto zaobserwowano, że w latach 2014-2017 liczba robotów na jedno gospodarstwo wzrosła, podobnie jak dobowy uzysk mleka z robota oraz od krowy, wzrosła też liczba dojów w ciągu doby oraz szybkość oddawania mleka. Udowodnione, statystyczne różnice między poziomem parametrów doju w objętych badaniami krajach prawdopodobnie mogą być efektem zróżnicowanego potencjału genetycznego dojonych krów oraz różnorodności bazy paszowej.

**Słowa kluczowe:** automatyczny system doju, parametry doju, bydło mleczne

## INTRODUCTION

Currently, in the world, the dairy industry has been servicing more than seven billion consumers and provides a revenue to about a billion people living off the work on their dairy farms (IFCN, 2017; USDA, 2017). This market has been developing very intensively and has been implementing innovative technologies, which could lead to a very accurate monitoring of the cows in the herd and to improve their welfare and performance (Bach et al., 2009; Shevchenko and Aliev, 2013). Currently, in the world, the largest dairy cattle farms are situated in the US, whereas the most milk is produced by countries from the European Union (Douphrate et al., 2013; Ghosh et al., 2017; ICAR 2018). Milking robots are well known in many countries (Douphrate et al., 2013; Gaworski et al., 2016; Tremblay et al., 2016; Santos et al., 2018). In 1992, as the first company in the world, the Dutch company Lely produced a milking robot named "Astronaut" (Jacobs and Siegford, 2012). In turn, DeLaval installed its first robot in 1998 in Sweden. The robots were first used on the Polish market in 2010 (Kubiak-Włodarczyk, 2017). As De Koning and Rodenburg (2004) stress, in 2004, there were more than 2,200 milking robots by various manufacturers, working all over the world. Another important date in the development of the automatic milking system (AMS) was the year 2009, when Lely was the first company to install devices used to determine the chemical components of milk in its milking robot, the Astronaut A3 NEXT. In 2014, the same company celebrated the production of its twenty thousandth milking robot (Lipiński, 2015). Currently, this number is estimated for about 30 thousand (Lely International, 2018). The computer software enclosed to the contemporary robot, which, in essence, is a herd management system, records more than 100 milking parameters (Jacobs and Siegford, 2012; Carlström et al., 2013). An in-depth analysis of the data accumulated in this manner, particularly for herds bred by the best breeds, can be used to determine the factors, and thus the solutions which have the largest impact on the success of milk production (Forsbäck et al., 2010; Tremblay et al., 2016; Tse et al., 2018). Their propagation among the remaining breeders is the best way to ensure the development of the entire dairy sector.

The purpose of the study was to compare selected parameters recorded by the automatic milking system Lely Company in selected European countries and the US in 2014-2017.

## MATERIALS AND METHODS

The analysis assumed numerical material obtained from the data recording system by Lely concerning: the average number of robots per herd (n), the number of cows per robot (n), the daily milk yield per robot (kg), the daily milking frequency (n), the daily number of refusals (n), the milking speed (kg/min), the daily milk yield per cow (kg), the fat and protein content (%) and the consumption of concentrated fodder per 100 kg of milk (kg). The accumulated data were recorded in the Czech Republic (CZ), France (FR), Germany (DE), Italy (IT), Latvia (LV), Lithuania (LT), the Netherlands (NL), Poland (PL) and the United States (US) in 2014-2017. In total, the results recorded by 9,365 robots, distributed in 6,941 herds and concerning the productivity of 521,000 cows were analyzed. No approval of the Local Ethics Committee for Experimental Animals was needed to perform the study.

A statistical analysis of the numerical material collected was carried out, applying the two-factor variance analysis, using the SAS v. 9.4 software. The following effects were taken into account in the linear model describing the variability of milking parameters: the country, the milking year and the country × milking year interaction (SAS Institute Inc., 2014).

## RESULTS AND DISCUSSION

The variance analysis indicated a highly significant impact of the country on all milking parameters (Table 1). A similar rule was also proven by Waśkowicz et al. (2014), who analyzed the performance of milking robots in EU countries and the US in 2012-2013. The differences identified among the compared countries in milk yield and composition, as well as the milking speed, were generally justified by different genetic potentials of the cows (Waśkowicz et al., 2014).

**Table 1.** F - statistic and significance (marked by *) of the impact of main factors and interactions on milking parameters

| Trait | Year (Y) | Country (C) | Y×C |
|---|---|---|---|
| Average number of robots per herd (n) | 43.44** | 571.98** | 10.33** |
| Number of cows per robot (n) | 4.46** | 96.09*** | 9.33** |
| Daily milk yield per robot (kg) | 29.07** | 220.62** | 2.93** |
| Daily milking frequency (n) | 3.56* | 118.61** | 6.27** |
| Daily number of refusals (n) | 7.43** | 711.63** | 9.55** |
| Milking speed (kg/min) | 37.33** | 630.96** | 4.97** |
| Daily milk yield per cow (kg) | 41.16** | 585.65** | 4.07** |
| Fat content (%) | 2.29 | 200.09** | 3.90** |
| Protein content, % | 72.55** | 188.23** | 4.58** |
| Consumption of concentrated fodder per 100 kg of milk (kg) | 39.66** | 1,343.41** | 13.49** |

*P≤0.05; **P≤0.01

According to Fernandes et al., (2014), the biological and economic potential of dairy cattle breeding is extremely diversified in different countries. Based on the data presented by ICAR (2018), it can be concluded that, among the countries assumed with the study, the most cows were milked in the US (9,317 thous., 2015 year), then in DE (4,217 thous., 2016 year), FR (3,629 thous., 2016 year), PL (2,520 thous., 2017 year), IT (1,923 thous., 2014 year), NL (1,608 thous., 2016 year), CZ (365 thous., 2017 year), LV (163 thous., 2016 year) and LT (144 thous., 2017 year). In all of the studied countries, the Holstein-Friesian breed was the dominant one, however, the share of this breed in the overall headage is quite diversified (ICAR 2018).

The study indicated that the year of milking statistically differentiated the majority of the studied features, with the exception of fat content in milk (Table 1). It was further indicated that the country and country × year of milking interaction was the source of variability for all controlled features.

In the studied countries, in farms breeding dairy cattle, the average number of milking robots per herd was 1.98 in 2014-2017 (Table 2). Depending on the country, this number was from 1.43 (France) to 2.71 (the US). In Poland, it was 1.82 pcs. In the majority of countries, an increase in the number of robots purchased by farms was observed in 2014-2017, in average from 1.91 (in 2014) to 2.06 (in 2017) per herd.

The highest dynamic of change in this aspect was claimed in Lithuania, i.e. from 2.23 to 2.77 pcs. According to earlier studies conducted by Waśkowicz et al. (2014) in 2012-2013, the average number of installed milking robots per country fluctuated from 1.31 (France) to 2.72 (the Czech Republic), with 1.80 in Poland. The stock assigned to each robot is an important indicator which determines the daily milk yield for the cow (Castro et al., 2012; Gaworski and Boćkowski, 2012; Tse et al., 2018). The present study showed that, in the four-year period of the study, the largest stock of cows was recorded in Poland (59.03 cows per robot) and in Germany (58.95 cows), whereas the smallest - in the Netherlands (53.06 cows), then in Latvia (53.13 cows) (Table 2). Gaworski et al. (2016) point to a low cow stock per robot in Latvia and the possibility of economic losses resulting from it. The studies indicated that, in the successive years, the robot stock was statistically diversified and that a single increasing or decreasing trend cannot be isolated (Table 2).

**Table 2.** Average number of robots per herd (n), number of cows per robot (n) and milking parameters according to country and milking year

| Year | Statistics | Country | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CZ | FR | DE | IT | LV | LT | NL | PL | US | |
| | | Average number of robots per herd (n) | | | | | | | | | |
| 2014 | $\bar{x}$ | 2.27 | 1.38 | 1.61 | 1.58 | 1.99 | 2.23 | 1.85 | 1.76 | 2.56 | 1.91 |
| 2015 | $\bar{x}$ | 2.08 | 1.42 | 1.61 | 1.56 | 2.18 | 2.14 | 1.91 | 1.80 | 2.65 | 1.93 |
| 2016 | $\bar{x}$ | 2.17 | 1.46 | 1.64 | 1.71 | 2.16 | 2.57 | 1.97 | 1.86 | 2.76 | 2.03 |
| 2017 | $\bar{x}$ | 2.12 | 1.48 | 1.67 | 1.80 | 1.98 | 2.77 | 2.00 | 1.87 | 2.88 | 2.06 |
| Total | $\bar{x}$ | 2.16 | 1.43 | 1.63 | 1.66 | 2.08 | 2.43 | 1.93 | 1.82 | 2.71 | 1.98 |
| | CV | 4.78 | 2.84 | 1.67 | 6.35 | 8.18 | 16.08 | 3.17 | 2.85 | 4.85 | 20.93 |
| | | Number of cows per robot (n) | | | | | | | | | |
| 2014 | $\bar{x}$ | 55.37 | 53.46 | 58.37 | 54.25 | 52.99 | 57.94 | 51.99 | 61.70 | 54.95 | 55.67 |
| 2015 | $\bar{x}$ | 56.53 | 53.21 | 58.32 | 55.19 | 52.85 | 51.11 | 53.28 | 59.67 | 55.56 | 55.08 |
| 2016 | $\bar{x}$ | 54.54 | 53.08 | 59.24 | 54.71 | 53.15 | 51.73 | 54.52 | 57.65 | 55.44 | 54.90 |
| 2017 | $\bar{x}$ | 54.31 | 54.16 | 59.87 | 56.39 | 53.51 | 52.65 | 52.43 | 57.12 | 55.22 | 55.07 |
| Total | $\bar{x}$ | 55.19 | 53.48 | 58.95 | 55.13 | 53.13 | 53.36 | 53.06 | 59.03 | 55.29 | 55.18 |
| | CV | 4.22 | 2.39 | 1.60 | 3.07 | 4.17 | 6.80 | 2.45 | 4.15 | 1.21 | 5.42 |
| | | Daily milk yield per robot (kg) | | | | | | | | | |
| 2014 | $\bar{x}$ | 1,369 | 1,456 | 1,498 | 1,505 | 1,355 | 1,299 | 1,362 | 1,488 | 1,845 | 1,464 |
| 2015 | $\bar{x}$ | 1,502 | 1,463 | 1,523 | 1,575 | 1,400 | 1,188 | 1,416 | 1,521 | 1,847 | 1,493 |
| 2016 | $\bar{x}$ | 1,477 | 1,455 | 1,554 | 1,580 | 1,369 | 1,298 | 1,470 | 1,486 | 1,858 | 1,505 |
| 2017 | $\bar{x}$ | 1,481 | 1,468 | 1,580 | 1,642 | 1,487 | 1,391 | 1,472 | 1,579 | 1,898 | 1,555 |
| Total | $\bar{x}$ | 1,457 | 1,461 | 1,538 | 1,575 | 1,403 | 1,294 | 1,430 | 1,518 | 1,862 | 1,504 |
| | CV | 5.93 | 5.07 | 3.99 | 6.90 | 8.03 | 8.04 | 4.44 | 5.01 | 2.25 | 11.33 |
| | | Daily milking frequency (n) | | | | | | | | | |
| 2014 | $\bar{x}$ | 2.53 | 2.5 | 2.66 | 2.74 | 2.68 | 2.79 | 2.68 | 2.78 | 2.78 | 2.68 |
| 2015 | $\bar{x}$ | 2.63 | 2.53 | 2.65 | 2.74 | 2.71 | 2.78 | 2.72 | 2.77 | 2.80 | 2.70 |
| 2016 | $\bar{x}$ | 2.68 | 2.51 | 2.62 | 2.75 | 2.81 | 2.72 | 2.70 | 2.76 | 2.79 | 2.70 |
| 2017 | $\bar{x}$ | 2.69 | 2.46 | 2.61 | 2.72 | 2.81 | 2.72 | 2.79 | 2.80 | 2.78 | 2.71 |
| Total | $\bar{x}$ | 2.63 | 2.50 | 2.63 | 2.74 | 2.75 | 2.75 | 2.72 | 2.78 | 2.79 | 2.70 |
| | CV | 2.86 | 2.61 | 1.81 | 1.94 | 3.82 | 3.44 | 2.17 | 1.58 | 1.20 | 4.10 |

**Table 2.** Continued

| Year | Statistics | Country | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CZ | FR | DE | IT | LV | LT | NL | PL | US | |
| | | Daily number of refusals (n) | | | | | | | | | |
| 2014 | $\bar{x}$ | 2.22 | 1.83 | 2.56 | 1.70 | 2.88 | 4.15 | 3.57 | 2.34 | 1.43 | 2.52 |
| 2015 | $\bar{x}$ | 2.47 | 1.89 | 2.62 | 1.79 | 1.86 | 4.21 | 3.57 | 2.33 | 1.42 | 2.46 |
| 2016 | $\bar{x}$ | 2.68 | 1.88 | 2.53 | 1.82 | 1.77 | 4.35 | 3.32 | 2.41 | 1.36 | 2.46 |
| 2017 | $\bar{x}$ | 2.42 | 1.73 | 2.49 | 1.77 | 2.03 | 3.98 | 3.39 | 2.17 | 1.41 | 2.38 |
| Total | $\bar{x}$ | 2.45 | 1.83 | 2.55 | 1.77 | 2.13 | 4.17 | 3.46 | 2.31 | 1.40 | 2.45 |
| | CV | 10.05 | 7.23 | 3.80 | 6.08 | 23.89 | 11.86 | 7.53 | 6.51 | 6.88 | 35.33 |

CV – coefficient of variation (%); $\bar{x}$ – mean; Cz - Czech Republic FR - France, DE - Germany, IT - Italy LV - Latvia, LT - Lithuania, NL – Netherlands, PL – Poland, US – United States

It was observed that, in 2017, the stock per robot was larger by 0.60 cow, compared to 2014. However, an explicit decreasing trend was observed for the feature in Poland only. In earlier studies, Waśkowicz et al. (2014) observed that, in Poland, more cows were assigned to a single robot than anywhere else – approx. 64. Therefore, comparing to the currently analyzed period, a decrease by 5 cows, in average, was noticed. In turn, in Germany, the robot stock increased relative to an earlier period by 6 cows.

The average herd size was calculated based on the information on the average number of robots per herd and the number of cows per one robot in the studied countries. Figure 1 presents information on the average herd size in the mass population and on farms equipped with AMS (ICAR, 2018; THUNEN, 2018). According to this listing, the largest herds in the mass population of dairy cows were found in CZ (314 cows) and the US (214), and the smallest ones - in LT (8.1 cows) and PL (8.8 cows). What is noteworthy, in CZ and the US, the average size of herds equipped with AMS was clearly smaller than as accounted for in the mass population. In turn, in terms of size, the robotized Dutch herds were generally larger than as accounted for in the mass population by a mere 1.4 cow. The remaining of the studied countries was characterized by a higher herd headage in AMS, compared to the mass population.

The basic parameter which contributes greatly to the breeder's return on investment is the daily milk yield from a milking robot (Tse et al., 2018). The costs of producing milk are directly related to the profitability of production. In 2014, the average cost of producing 100 kg of milk was USD 40.5 in the world. It should be noted that, significant differences were identified among various parts of the world in this aspect - the lowest production cost was recorded in Uganda - USD 8.5, and the highest - in Switzerland, of USD 106 (IFCN, 2017). In the Czech Republic, these costs were approx. USD 33 in 2017 (THUNEN, 2018).

The study indicated that each day the most milk was obtained from one robot in the US – 1,862 kg, and then in Italy – 1,575 kg (Table 2). In these countries, high milk yield obtained by robot entailed the largest amount of milk obtained from a cow, respectively: 33.48 and 30.81 kg, as well as the milking speed, respectively: 2.74 and 2.79 kg/min, or the daily number of milkings, respectively: 2.79 and 2.74 (Table 3). A similar rule was also proven by Waśkowicz et al. (2014) in his earlier study. Considering the aforementioned indicators referring to all of the countries, combined, in the successive years, this study indicated a growing milk yield from a milking robot and individual - from each cow, increased milking speed and the frequency of visits at the milking robot (Table 2 and Table 3).

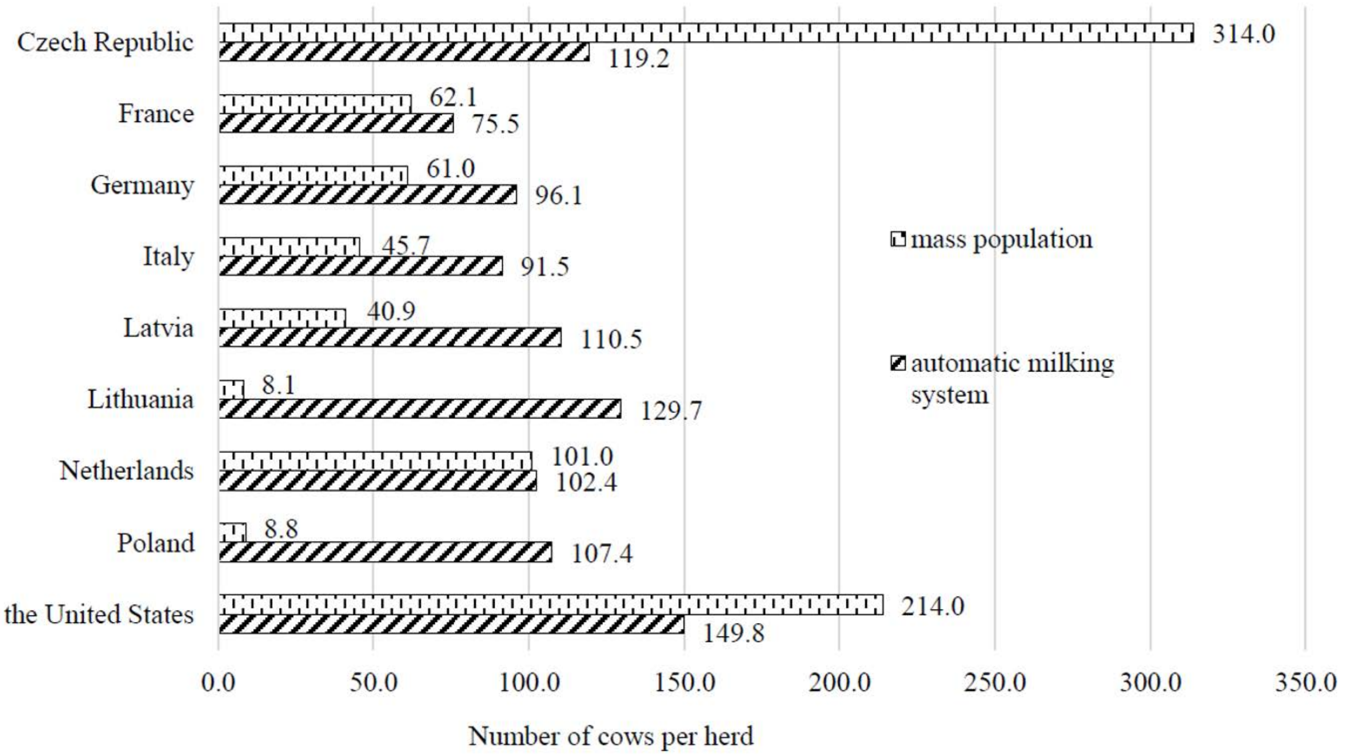


**Figure 1.** The average herd size in mass population and on farms equipped with automatic milking system according to country

**Table 3.** Milking parameters according to country and milking year

| Year | Statistics | Country | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CZ | FR | DE | IT | LV | LT | NL | PL | US | |
| | | Milking speed (kg/min) | | | | | | | | | |
| 2014 | $\bar{x}$ | 2.40 | 2.56 | 2.46 | 2.77 | 2.13 | 2.13 | 2.45 | 2.40 | 2.65 | 2.44 |
| 2015 | $\bar{x}$ | 2.41 | 2.54 | 2.43 | 2.78 | 2.08 | 2.08 | 2.44 | 2.41 | 2.73 | 2.43 |
| 2016 | $\bar{x}$ | 2.43 | 2.55 | 2.46 | 2.78 | 2.05 | 2.06 | 2.47 | 2.47 | 2.78 | 2.45 |
| 2017 | $\bar{x}$ | 2.43 | 2.54 | 2.52 | 2.83 | 2.29 | 2.14 | 2.53 | 2.53 | 2.82 | 2.51 |
| Total | $\bar{x}$ | 2.42 | 2.55 | 2.47 | 2.79 | 2.14 | 2.10 | 2.47 | 2.45 | 2.74 | 2.46 |
| | CV | 2.46 | 1.98 | 2.55 | 2.30 | 5.76 | 3.39 | 2.76 | 3.36 | 3.35 | 9.42 |
| | | Daily milk yield per cow (kg) | | | | | | | | | |
| 2014 | $\bar{x}$ | 26.86 | 28.37 | 27.24 | 30.33 | 24.05 | 22.22 | 27.49 | 26.47 | 32.68 | 27.30 |
| 2015 | $\bar{x}$ | 27.51 | 28.73 | 27.58 | 30.53 | 25.20 | 23.16 | 27.82 | 26.84 | 33.45 | 27.87 |
| 2016 | $\bar{x}$ | 27.80 | 28.53 | 27.38 | 30.98 | 25.60 | 22.13 | 27.85 | 27.00 | 33.73 | 27.89 |
| 2017 | $\bar{x}$ | 28.05 | 28.09 | 27.61 | 31.41 | 27.53 | 23.23 | 28.94 | 28.53 | 34.07 | 28.61 |
| Total | $\bar{x}$ | 27.55 | 28.43 | 27.45 | 30.81 | 25.59 | 22.68 | 28.03 | 27.21 | 33.48 | 27.92 |
| | CV | 2.95 | 3.23 | 2.55 | 3.91 | 6.22 | 5.25 | 2.92 | 4.02 | 2.30 | 10.89 |

**Table 3.** Continued

| Year | Statistics | Country | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CZ | FR | DE | IT | LV | LT | NL | PL | US | |
| | | Fat content (%) | | | | | | | | | |
| 2014 | $\bar{x}$ | 3.89 | 4.01 | 4.11 | 3.75 | 3.85 | 4.22 | 4.47 | 4.12 | 3.85 | 4.03 |
| 2015 | $\bar{x}$ | 3.90 | 4.06 | 4.10 | 3.76 | 3.99 | 4.11 | 4.42 | 4.11 | 3.78 | 4.03 |
| 2016 | $\bar{x}$ | 3.95 | 4.10 | 4.11 | 3.82 | 4.02 | 4.24 | 4.41 | 4.03 | 3.79 | 4.05 |
| 2017 | $\bar{x}$ | 3.96 | 4.11 | 4.06 | 3.81 | 3.99 | 4.18 | 4.36 | 3.93 | 3.81 | 4.02 |
| Total | $\bar{x}$ | 3.93 | 4.07 | 4.10 | 3.78 | 3.96 | 4.19 | 4.41 | 4.05 | 3.81 | 4.03 |
| | CV | 2.32 | 1.80 | 1.75 | 2.68 | 3.86 | 3.47 | 1.67 | 2.74 | 1.75 | 5.21 |
| | | Protein content (%) | | | | | | | | | |
| 2014 | $\bar{x}$ | 3.5 | 3.34 | 3.51 | 3.39 | 3.27 | 3.54 | 3.67 | 3.44 | 3.19 | 3.43 |
| 2015 | $\bar{x}$ | 3.36 | 3.27 | 3.38 | 3.30 | 3.28 | 3.33 | 3.51 | 3.38 | 3.07 | 3.32 |
| 2016 | $\bar{x}$ | 3.36 | 3.30 | 3.41 | 3.33 | 3.26 | 3.34 | 3.51 | 3.37 | 3.08 | 3.33 |
| 2017 | $\bar{x}$ | 3.40 | 3.35 | 3.43 | 3.37 | 3.32 | 3.33 | 3.53 | 3.33 | 3.11 | 3.35 |
| Total | $\bar{x}$ | 3.41 | 3.31 | 3.43 | 3.35 | 3.28 | 3.39 | 3.56 | 3.38 | 3.11 | 3.36 |
| | CV | 2.40 | 1.73 | 2.21 | 1.98 | 2.65 | 3.48 | 2.60 | 1.51 | 2.13 | 4.13 |
| | | Consumption of concentrated fodder per 100 kg of milk (kg) | | | | | | | | | |
| 2014 | $\bar{x}$ | 16.43 | 14.38 | 15.82 | 12.82 | 15.54 | 16.94 | 19.71 | 15.33 | 15.51 | 15.83 |
| 2015 | $\bar{x}$ | 16.75 | 14.06 | 15.38 | 12.68 | 14.71 | 17.39 | 19.93 | 14.99 | 15.44 | 15.70 |
| 2016 | $\bar{x}$ | 16.51 | 13.73 | 14.97 | 12.99 | 14.07 | 17.60 | 20.33 | 14.37 | 15.19 | 15.53 |
| 2017 | $\bar{x}$ | 16.10 | 13.91 | 14.70 | 12.78 | 13.35 | 16.36 | 20.63 | 14.55 | 15.04 | 15.27 |
| Total | $\bar{x}$ | 16.45 | 14.02 | 15.22 | 12.81 | 14.42 | 17.07 | 20.15 | 14.81 | 15.30 | 15.58 |
| | CV | 1.95 | 2.58 | 2.90 | 1.48 | 7.13 | 5.39 | 2.47 | 3.10 | 1.46 | 13.36 |

CV – coefficient of variation (%); $x$ – mean; Cz - Czech Republic FR - France, DE - Germany, IT - Italy LV - Latvia, LT - Lithuania, NL – Netherlands, PL – Poland, US – United States

This is the more essential that, from 2007 to 2015, there were three global dairy crises lasting up to several months in some countries. This was therefore a very difficult period for dairy breeders (IFCN, 2017). In turn, the lowest milking parameter values (daily milk yield per robot and cow, the milking speed and the number of visits at the milking robot) were observed in Lithuania and Latvia, which could stem from the poorer genetic value of the local cattle (Table 2 and Table 3). This is the more surprising, since, in Latvia, milk production is the second most important agricultural sector (Nipers et al., 2017). In turn, in Lithuania, milk production was responsible for approx. 16.7% of the total agricultural production in 2014-2016 (EC, 2017). What is noteworthy, in 2016, the cow population in Latvia and Lithuania was, respectively: 9.2 and 11.3% of cows in EU-28 (European Union).

In this year, Polish cattle made up for 12.2%, Italian - for 20.2%, and German - for 15.6% of the dairy cattle population in the EU (EC, 2017). The study indicated that, among the controlled populations, in successive reporting years, the daily milk yield obtained by a milking robot increased by 91 kg, the daily milk yield from a cow - by 1.31 kg, and the number of milkings performed by each cow - by 0.03, and the milking speed – by 0.07 kg/min (Table 2 and Table 3).

In a study conducted by Pezzuolo et al. (2017), the average daily milk yield per robot was 1 950 kg with an average stock per robot of 52.9 cows. While in the study by Tremblay et al. (2016), daily milk yield was 1 626.80 kg, with 50.53 cows assigned to a single robot, and the average milking frequency was 2.91 a day, with 6.84 minutes in average spent, being milked by the robot,

High fat and protein contents in milk prove the high concentrations of dry matter. These parameters are extremely important for the dairy industry, particularly in the production of cheese. More cheese can be manufactured out of milk with high dry matter content, and particularly with high protein content, compared to milk with lower concentrations (Wedholm et al., 2006). Milk components fluctuate in time, influenced by the nutrition and climatic conditions in the country (Collier et al., 2018; Pryce et al., 2018). According to Bach et al. (2009), Endres and Salfer (2017), increasing milking frequency in AMS through induced cattle movement towards the robot can have negative impact on the amount of milk obtained and its composition. In the present paper, the lowest fat and protein content was recorded in countries with the highest milking capacity, i.e. the US, respectively for fat and protein content: 3.81%, 3.11% and Italy: 3.78 and 3.35 % (Table 3). The highest fat and protein contents were clearly observed in the Netherlands, respectively: 4.41 and 3.56 %. The Dutch advantage over other countries most likely stems from the fact that the cows undergo careful selection there to obtain high protein content in milk (INTERBULL, 2017).

Therefore, interested in achieving a high level of features, breeders from other countries should employ the Dutch breeding model. What is noteworthy, the composition of milk, as expressed with the fat and protein content, has been statistically changing in individual countries in successive reporting years, without however displaying any clear trend. This is proven by the significance of the country x milking year interaction. Referring the results obtained to earlier studies conducted by Waśkowicz et al. (2014), it was claimed that the average fat and protein contents in 2014-2017 obtained in countries where cows have the highest milking capacity, i.e. in the US and Italy, have slightly changed relative to prior studies. In the US, the fat content decreased by 0.04 percentage points (p.p.), whereas the protein content increased by the same value. In Italy, the fat content increased by 0.13 p.p., whereas the protein content - by 0.04 p.p. In turn, in the Netherlands, a decrease in the contents of both elements was recorded - respectively, by 0.07 p.p. for fat and 0.14 p.p. for protein.

Other parameters recorded by the AMS included: consumption of concentrated fodder dispensed by the milking robot per 100 kg of milk (does not include the concentrated fodder served on the fodder table) and the average number of refusals per cow throughout the day (Table 2 and Table 3). Refusals or refused milkings are the recorded entries of cows to the milking robot for cows, for which sufficient time has not elapsed from the last milking. A high number of refusals points to a high activity of the herd, which provides for milkings in regular intervals and lower work expenditure, which would be otherwise spent on driving in cows for late milking.

Feed efficiency is one of the most important indicators which have been currently considered in the economics of milk production. For instance, since 2015, it has been taken into account when the breeding value of Australian cattle was examined (Pryce et al., 2018). The highest level of fodder consumption per 100 kg of milk was recorded in the Netherlands: 20.15 kg and in Lithuania: 17.07 kg (Table 3). The highest number of refusals was also recorded in these countries, respectively: 3.46 and 4.17 (Table 2).

The lowest fodder consumption level was recorded in Italy and in France, respectively: 12.81 kg and 14.02 kg. In turn, the lowest number of refusals was recorded in the US - 1.40 and in Italy - 1.77. These facts lead to a conclusion that, in countries like the Netherlands and Lithuania, nutrition is predominantly based on hay and grass silage, which are the main bases of forage, which is why these cows display a higher demand for nutrients, compared to concentrate feeding. In consequence, cows are more eager to visit the robot, where they recharge on energy nutrients from their basic dose. This is confirmed by the results of a study conducted by Bach et al. (2009). In turn, in countries such as Italy or the US, nutrition is based on maize silage, which serves as the basic forage. It is worth mentioning that in the studied countries in 2014-2017 consumption of concentrated fodder per 100 kg of milk decreased by o 0.56 kg, while the daily number of refusals by 0.14. The differences found among these countries in terms of fodder consumption can stem from the amount of energy supplied to cows on the fodder table, and from different compositions of the fodder dose (Collier et al., 2018). When a high energy level is guaranteed in the basic dose and when the robot offers a lower amount of concentrated fodder, cows are less motivated to visit the robot. This is the probable cause of lower refusal rates.

## CONCLUSIONS

A high, significant impact of the country was claimed on all of the controlled milking parameters, which is most likely caused by varying genetic potentials of the cows themselves, including their varying breeds, and the diversity of fodders used. In the 2014-2017 reporting period, general, beneficial trends were identified in the controlled milking parameters, which can prove the effectiveness of breeding and the mastering of the automating milking system by the breeders using it. Considering however the highly significant interaction of country × milking year, it can be concluded that the changes observed were characterized by varying dynamics and opposite directions, depending on the country.

Between 2014-2017 in studied countries the average number of milking robots per dairy cattle herd was 1.98, with the smallest number of animals per robot in France and the highest in the US. It was observed that, in 2017, the stock per robot was larger by 0.60 cows, compared to 2014. The highest daily milk yield per one robot and per one cow was obtained in the US and then in Italy, the lowest in Lithuania. At the same time highest number of refusals per day was recorded in Lithuania, while the lowest in the US and Italy.

The authors believe that the obtained results will constitute a good reference point for breeders in other countries implementing an automatic milking system.

Especially since the scientific literature on the subject lacks similar cross-sectional results. At the same time, they can provide an indication of the herd size (the number of robots used in the herd) and the optimal cow density per milking unit, which guarantees a high milk yield from the robot.

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