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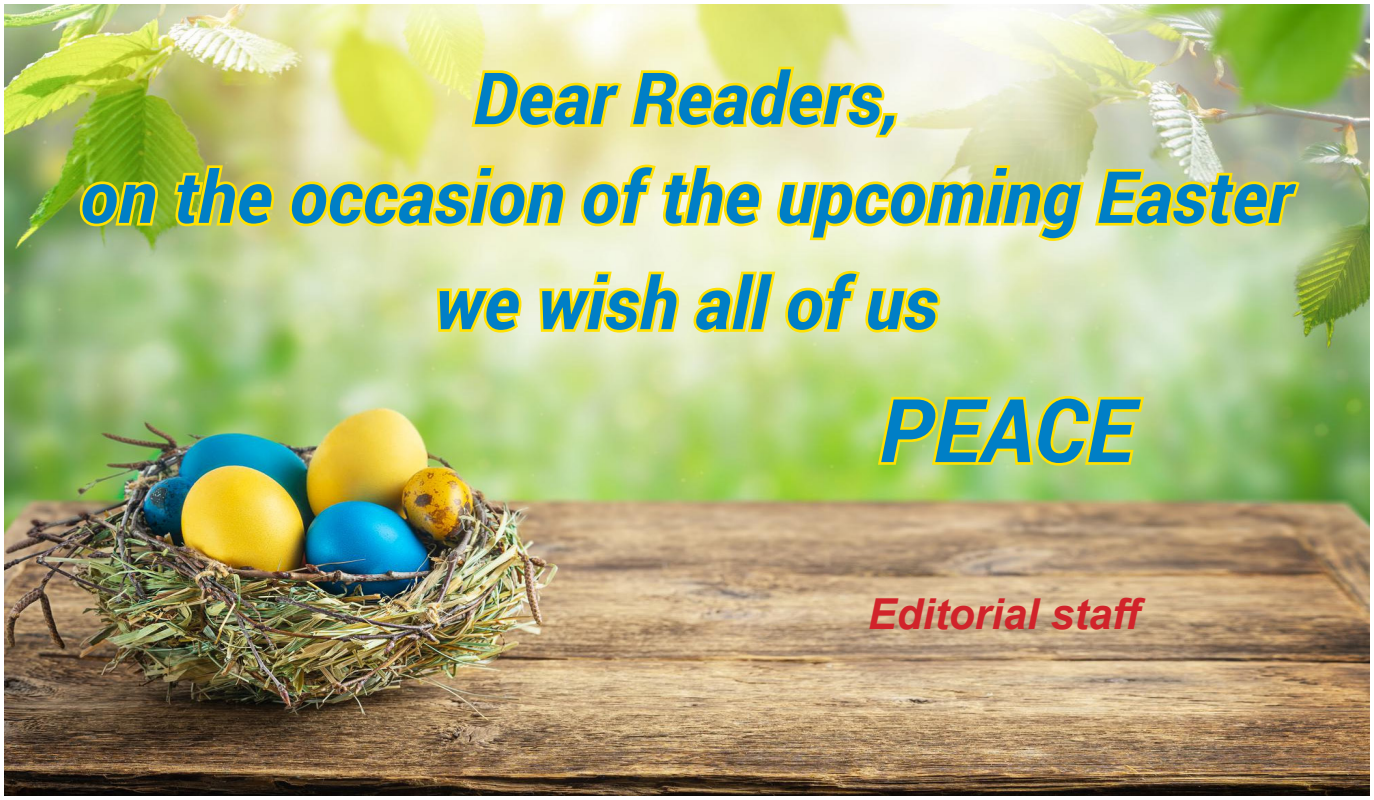
THE CONCEPT OF A PROCONSUMER HYDRO POWER PLANT WITH A SPECIAL BEARING FOR THE MAIN SHAFT



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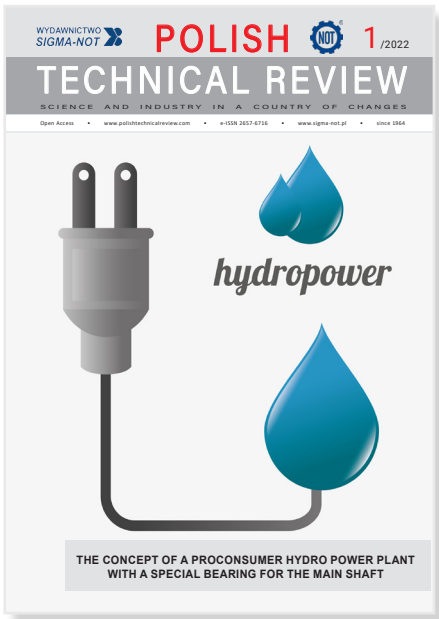

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AUTOMATION OF DAIRY COW FEEDING AS THE METHOD FOR REDUCTION OF GREENHOUSE GAS EMISSION, ORIGINATING IN ANIMAL PRODUCTION

AUTOMATYZACJA ŻYWIENIA KRÓW MLECZNYCH JAKO SPOSÓB REDUKCJI EMISJI GAZÓW CIEPLARNIANYCH POCHODZĄCYCH Z PRODUKCJI ZWIERZĘCEJ

***Summary**: The increasing number of the population and the related intensification of animal-origin food production are indicated as the source of climatic changes. The present paper contains the information concerning the impact of animal production on anthropogenic emission of greenhouse gases (GHG). A special attention was paid to the problems connected with milk production. The selected methods for mitigation of GHG emission, derived from dairy farms, were presented. The recent part of the paper was dedicated to the comparison of energy consumption in automatic (AFS) and conventional (CFS) feeding systems and the potential profits, resulting from the application of automatic feeding systems.*

***Keywords**: automatic feeding, cow, greenhouse gas, animal production, milk*

***Streszczenie**: Rosnąca liczba ludności i związana z tym intensyfikacja produkcji żywności pochodzenia zwierzęcego wskazywane są jako źródło zmian klimatycznych. W niniejsze pracy zawarto informacje dotyczące wpływu produkcji zwierzęcej na antropogeniczną emisję gazów cieplarnianych (GHG). Szczególną uwagę poświecono kwestiom związanym z produkcją mleka. Przedstawiono także wybrane metody łagodzenia emisji GHG pochodzącej z gospodarstw mlecznych. Ostatnią część pracy poświęcono porównaniu energochłonności automatycznych (AFS) i konwencjonalnych (CFS) systemów żywienia oraz potencjalnym korzyściom wynikającym z użytkowania automatycznych systemów żywienia.*

***Słowa kluczowe**: automatyczne żywienie, krowa, gazy cieplarniane, produkcja zwierzęca, mleko*

Introduction

Animal-origin food products constitute a significant source of energy and protein in human diet. They deliver micro-elements, including many essential vitamins and mineral compounds [2]. At present, all over the world, about 56 billion of terrestrial animals are managed and slaughtered for consumption purposes; according to the forecasts up to 2050, their number will be doubled [22]. The increase of demand on food products results directly from the increase of population in our Globe. It is estimated that in 2050, the human population will reach 9.5–9.8 billion persons, and in 2100 – even 11.2 billion inhabitants. It raises concerns that one of the main problems which the humanity will be faced with, will be ensuring of food safety [2, 13].

Production of any kind of food, irrespectively of the manufacturing system, has a certain impact on natural environment. It is foreseen that in the coming years, the number of animals kept for meat, eggs as well as for milk production will cause the increase of the emission of GHG [22]. Nevertheless, the system of the sustainable agriculture becomes the subject of greater and greater interest among the producers and consumers. To be called sustainable, the agricultural products must ensure the combination of the appropriate feeding value of the supplied goods (safe and nutritious) and minimization of its social and economic impact (easily available and approvable in respect of price) and environmental effect [2]. The increasing interest in the products produced in environment-friendly way among the consumers is one of the driving forces of the changes in breeding. Due to its influence, the general purposes of breeding were de-oriented from maximization of production towards production, focused on effectiveness and considering the restrictions of natural environment [4].

The changes which occurred in the earlier mentioned context are perfectly illustrated in the area of milk production. As early as at the beginning of the 20th century, the mean daily milk production in the United States did not exceed 5 kg of milk from one cow and the mean dairy herd included no more than 5 dairy cows. On the contrary, in the first ten years of the 21st century, the average American cow produced ca. 30 kg of milk/day and 60% of the total production was implemented in the herds consisting of more than 500 animals [2]. During the recent 60 years, the milking performance of cow was by 4 times increased and is still increasing at the rate of ca. 130 kg annually [25].

The mentioned progress was possible owing to understanding of dairy cow biology and utilization of the obtained knowledge

with the aim to develop the new technologies, e.g. insemination, improvement of genetic value, feeding and methods of management. The breeding work allowed the increase of production potential whereas the introduction of new technologies and management methods enabled its implementation [2, 25]. A final result of the discussed changes was reflected in the increase of "production effectiveness", expressed by the rise of milk production with the simultaneous reduction of consumption of the indispensable resources and lower amount of waste, derived from animal production. It has a key meaning in relation to lowering of demand on non-renewable and high-energetic resources (soil, water, fossils and fertilizers); at the same time, it supports the appropriate management of the environment. FAO experts estimate that in the future, due to the limited resources, it will be necessary to produce as much as 70% of the additional food with the participation of developed and highly effective technologies [2].

GHG emission from animal production

A significant part of the global emission of greenhouse gases (GHG) is connected with the eruption of volcanoes, forest fires, and sea and ocean storms, i.e. a natural one [21]. Nevertheless, agricultural production which accounts for 14–51% of participation in the total anthropogenic emission of GHG is indicated as an important factor, affecting the observed climatic changes [17, 26, 34]. We should also pay attention that the level of the discussed emission is not the same all over the world, e.g. the estimated participation of agriculture in total GHG emission in Poland is equal to 7.7%, including 29.8% of the total methane production and 78% of the national production of nitrogen oxides [34].

Total animal production constitutes 5–10% of all forms of agricultural activities [3, 26, 31]. The greatest part i.e. 44–59% of all GSG originating in animal breeding sector is generated by CH_4; CO_2 and N_2O are, respectively, characterized by 27-35% and 19.7-29% participation in the total emission. It is estimated that the supply chain, connected with the animal production, emits 9.2 GT of CO_2-equivalent to atmosphere; it constitutes 5% of anthropogenic emission of carbon dioxide [9, 26, 27]. According to other studies [22], the total animal production sector (connected directly and indirectly) may account even for 9% of the total CO_2 emission.

Cattle as emitter

Milk production and the related meat production account for 4% of the total anthropogenic emission, whereas the production of milk itself – 2.7 -2.9% [3, 26, 31]. We should also pay attention that the indicated values may be underestimated due to treating CO2 inhaled by the animals as biogenic [27] and not considered in the adopted assumptions [26, 35].

When speaking in general about animal production, we may state that the cattle, as being responsible for 65% of emissions (4.6 GT of CO_2-eq), is indicated as the most important emitter of greenhouse gases. Production of cow milk accounts for 20% and that one of beef for 45% of animal-origin emission. The remaining sectors of animal production such as production of milk and meat from small ruminants, production of milk and meat of buffaloes, production of pork and poultry meat and eggs generate 6-9% of GHG emission, each of them [26]. In the world scale, the ruminants produce about 80 million tonnes of CH_4 per year what constitutes 33% of anthropogenic production of the discussed compound [32] whereas according to different calculations, it may even amount to 35–40% [22].

The release of greater quantity of gases to atmosphere by ruminants as compared to monogastric animals is a result of their evolutionary adaptation of ruminants to utilization of structural hydrocarbons as a feeding source with the participation of cellulolytic and metanogenic microorganisms [21]. The processes occurring in rumen cause that 100g of digestible cellulose generate 10 litres of CO_2 and 3.5 l of CH_4. It means that one dairy cow is able to produce up to 650 litres of methane which is expelled by belching. The cow which has the annual milk yield at the level of 9 000 kg, produces 120–130 kg of CH_4 per year. Production of methane is connected with the energy loss amounting to 6.5% of gross energy supplied to the body but the mentioned losses may vary within the range of 2-12% [22, 32].

Carbon footprint of milk production

The consequence of the increase in production performance of cows during the recent 100 years is the increase in utilization of fuels in agricultural production [2]. Milk production, its collection and storage are connected with the consumption of energy, resulting from the need of supplying the electric energy to milking machines, water heaters, vacuum pumps, milk coolers and lighting. Most frequently, fossils are the source of the mentioned energy [9, 10]. The fossils are also used directly in cultivation of fodder plants, in transport of animals, utilization of manure, and in processing and transport of food [10].

The estimates concerning energy consumability in relation to milk, being carried out by evaluation of life cycle of the product (LCA, life cycle assessment) indicate that the greatest demand on energy, amounting to 40%, occurs at the stage of production. The simultaneous observations indicate that 25% of energy consumed directly for milking, milk refrigeration, and management of manure, ventilation and lighting in modern European dairy farms derives from non-renewable sources. 15% of energetic demand in the farms is covered by diesel oil (in Polish: ON). We should mention that the analyses indicated the mentioned oil combustion as the most important source of contamination, accounting for 72% of carbon emission whereas electric energy satisfied 27% of it [31].

The cited paper [31] indicates that the mean emission, resulting from diesel oil combustion, as expressed in CO_2-equivalent, amounted to 819 kg of CO_2-equivalent per lactating cow annually (125 kg of CO_2-equivalent per one tonne of FPCM) (fat and protein corrected milk). Apart from the emission resulting from fuel combustion, the farms participating in the studies emitted 201 kg of CO_2-equivalent per lactating cow (30 kg of CO_2-equivalent per one tonne of FPCM) as a result of electric energy consumption. The

total mean annual emission from farm was equal to 56 tonnes of CO_2-equivalent per lactating cow. It is worthy to mention that a significant part, i.e. 31% of energetic carbon footprint is responsible for feed preparation and distribution. The efficient utilization of direct energy sources (diesel oil, petroleum, electricity, etc.) is, therefore, one of the solutions, serving the reduction of environmental load and manufacturing costs in the studied sector.

Iranian scientists [10] indicate that the greatest participation in GHG emission, generated in connection with combustion process, directly and indirectly in dairy farm, belongs to fossils (74%), electricity (18%) and equipment (8%). The annual emission in the analysed farms amounted to 561.2 kg of CO_2-equivalent per cow.

Production of one kg of FPCM milk in Lithuania requires consumption of 37–62 g of oil-equivalent of fossils; the farms which manage 51–100 cows are characterized by the highest demand. Intestinal fermentation and manure are the main source of GHG emission in the discussed conditions. They account for 61–68% of the total emission, generated for production of 1 kg of milk. In turn, production connected with manufacture of concentrates is a source of 9–15% of the emission.

The studies conducted in Italy [9] revealed that production of 1 kg of FPCM necessitates 5.97±1.32 MJ energy, coming from non-renewable energy sources. The main factors determining their energy consumption include manufacture and transport of concentrates outside the farm (38.9%), feed production at the farm (16%) and energy used in the farm (20.55) connected with milking and refrigeration of milk, manure management and feed preparation and distribution.

Todde et al [31] as being cited earlier, inform that the mean annual energy consumption in the analysed group of farms amounted to 13 675 kg of diesel oil and 26 245 kWh of electric energy. As calculated to lactating cow and 1 kg of milk (FPCM), it was equal to 260 kg and 40 kg, respectively. It was also higher than that one obtained in the earlier Italian studies [1] where it was found within the limits of 154–183 kg of diesel oil per lactating cow. The analysis of energy consumption showed also that milking process and milk cooling were the most requiring processes in this aspect; they accounted for 23% and 29% of annual energy consumption. Additionally, the newer studies [31] cited in the present paragraph, revealed that the total diesel oil consumption in connection with the operations at farm and in field resulted from feed preparation and distribution (39%), field work connected with the cultivation (38%), management with manure (16%) and irrigation (7%).

The results of the researches conducted in Luxembourg [15] indicate that production of 1 000 kg of ECM milk (energy corrected milk) necessitated, in average, 4.96 GJ of energy (3.2–9.86 GJ) and the mean emission was equal to 1.31 kg CO_2-equivalent ECM^{-1} (0.8–2.09 kg). The authors of the mentioned development emphasize the fact that the observed differences have a source in effectiveness of utilizing the production means and not the intensity of production itself. It means that carbon footprint may be reduced. It requires, however, improvements in such important categories as feed base, fuel and electric energy utilization and investment in buildings and machines.

The methods of emission reduction

"Agriculture makes the contribution to the changes of climate and is dependent on the mentioned changes" [26]. As the milk producers experience the discussed changes and are dependent on them, they get involved in adaptation of management practices which facilitate administration of environment and care of it at each stage of milk production. The undertaken activities are aimed, *inter alia*, at the reduction of GHG emission, especially of methane and, also, minimization of loss of nutrients owing to effective balancing of feed rates or optimization of soil fertilization. Although there is no one effective practical way of reducing the impact on the environment, the combination of few strategies and available technologies may undoubtedly help achieving the assumed targets [2].

The increase of animal productivity and improvement of feed efficiency are the methods for reduction of negative influence of milk production. The simulation conducted by Rotz [25] revealed that the increase in cow milk yield was accompanied by the effective utilization of the nutrients. The comparison of cows with production potential amounting to around 16 000 kg and 7 260 kg of milk (3.5% of fat and 3.1% of protein content) per year shows that in the case of more productive animals, feed conversion was by 50% more effective. The yield of the managed animals resulted in the level of carbon footprint as calculated per one unit of the milk produced; in the case of highly productive cows, it was by 26% lower. The indicated dependence results from the difference in the quantity of animals necessary for obtaining the same summary amount of milk.

In the case of the animals under the above comparison, the energy footprint, defined as the amount of energy coming from fossils, necessary for production of one unit of milk, was different, depending on the adopted assumptions, by 10–30%, in favour of the cows with a higher annual productivity. The discussed differences were caused by the mentioned earlier lower demand on feed, resulting from its better feed efficiency what, in turn, means lower demand on energy used for its production and further handling.

Quality of the feeds and feeding value of the supplied feed rates are the factor, having a measurable effect on the level of GHG emission. Irish researchers [27] proved that the high cow yield was accompanied by the increase of GHG emission, as calculated per one litre of milk. According to the mentioned reports, the scale of CH_4 release to the environment is dependent on the quality of feed and manure handling. On the other hand, N_2O is affected by amount of protein in feeding ration and losses at the state of field cultivation. At the same time, literature data [22, 23] indicate that ensuring of the appropriate feeding may be the effective method for reduction of intra-systemic production of CH_4, both in the case of dairy and beef cattle. In this case, the solution consists in feeding the animals with more digestible concentrates of high quality, or feeding rates with a greater quantity of cereal grains. The discussed approach may result in the reduction of methane emission by 2–15%.

The health state of the animals is also a key factor. Better health state of animals, the reduced mortality rate and morbidity and the improved longevity result in the increase of productivity what, in effect of the mentioned above mechanisms and effect of distribution, gives lower GHG emission per unit of the product (milk, meat, etc.) [4, 21, 22]. It is perfectly illustrated by the example of methane emission [21]. In the situation when the annual production of dairy farm is equal to 800 000 kg of milk and it is produced by 200 cows with annual production of 4 000 kg, the quantity of CH_4, emitted to the atmosphere amounts to ca. 18.7 tonnes. The same quantity of milk, produced by 100 cows with the annual milk production at the level of 8 000 kg cause the emission of methane equal to 12.3 tonnes.

The effective feeding of cattle requires the possession of many groups of animals at the age before production period as well as those in the lactation period. Such approach prevents the loss of nutrients, guarantees lack of over-feeding certain animals and underfeeding the other cows; it is the most effective approach. One of the methods of implementing the mentioned above assumptions include the application of robotized feeding which facilitate the supply of the nutrients in a precise way and meet the requirements of the cows [29]. The technologies of the precise feeding are constantly developed and the mentioned systems are available at present in the market. Each technology which is favourable for improvement of the health state, reduced morbidity or mortality rate makes its contribution to the reduction of CH_4 and N_2O production. The precise feeding is a key to the improvement of production effectiveness, good health state of animals and reduction of animal-origin emissions [7].

The above given facts are reflected in the results of the studies [3, 11], indicating that more frequent feeding may have a positive effect on digestive processes owing to more stable conditions in rumen and higher total digestibility in the alimentary tract. Consumption of smaller meals with a higher frequency, based upon the constant model during a day, stabilises the conditions present in the rumen, reduces the frequency of incidence of sub-acute rumen acidosis (SARA) and is favourable for improvement of milk fat production.

The application of the targeted feed additives is another instrument, supporting the reduction of CH_4 production in the alimentary tract of cows. We should remember, however, that feeding rates (components and nutritive value) still must satisfy the requirements of animals, with the consideration of reproduction cycle stages [20].

Impact of energy source

Reduction of energy consumption contributes to reduction of carbon footprint and, additionally, it may positively affect the profitability of milk production [28]. In this context, it is worthy to mention that the consumption of non-renewable energy sources not only decreases the resources limited in respect of the quantity of fossils [2, 10] but it is also a significant source of CO_2 emission [9] and makes a contribution to the increase of carbon footprint, being strongly negative for the environment [10].

The solution indicated as mitigating the harmful emission from agricultural farms may be found in the utilization of energy carriers such as compressed natural gas, biodiesel, ethanol, hydrogen or electric energy; the mentioned factors are identified as alternative energy sources for transport. Although we cannot say that electric vehicles are emission-free (emission zero), completely friendly to the environment, etc., but based upon the studies of car vehicles [23], we may consider the battery-driven vehicles as being more effective in this respect in comparison to hybrids and the traditional (conventional) vehicles. The results submitted in the present paper indicate that the total emission, as expressed in CO2-equivalent and estimated by LCA method for the particular types of driving systems was presented as follows: conventional vehicles – 62 866 kg of CO_2-equivalent, hybrids – 40 733 kg of CO_2-equivalent whereas those ones, driven by batteries – 31 821 kg of CO_2-equivalent.

The alternative to fossils may be perceived in utilization of solar radiation (photovoltaic panels) which may reduce the costs of production as well as a negative impact of farms on the environment. Therefore, the optimization of production is possible, inter alia, owing to the choice of equipment, adaptation of infrastructure and the method of farm management [28].

The choice of the equipment to be used in the farm and their adaptation to the existing conditions is an important element serving the reduction of contamination and improving the production effectiveness. It has been confirmed by the studies conducted in Poland [12], indicating that agricultural tractor and the cooperating machines should be selected exactly to the needs of a given farm. It is important because the agricultural tractors and other oil-driven vehicles generate gases responsible for more than 6% of NO_x emission of all transport means, used in Poland. Other contamination generated by the mentioned vehicles (N_2O, PM, SO_2 and Pb) constitute 2% of the total transport emission [20].

When we assume that CO_2 does not have a negative impact on the animal health and only contributes to the increase of greenhouse gas effect, we cannot say the same about other gases (HC, CO, No_x), emitted in farm buildings during feeding with the use of classical feed mixer. The mentioned gases constitute a real threat to animals and humans. High emission of exhausts of agricultural tractors as compared to other transport means may affect the health and, also, quality of beef and milk [12]. We should also pay attention to the reports [20] focused on technical condition of agricultural equipment, employed at Polish farms; it affects the level of fuel consumption. Although – owing to the EU subsidies – the discussed situation is constantly improving, many measures are still required in order to modernize and adapt more environment-friendly technologies.

Automation of cow feeding

The level of energy consumption is strictly related to the effectiveness of the considered production system, technological level, the management method and the size of the herd. The so-far conducted analyses inform that the energy consumption, as

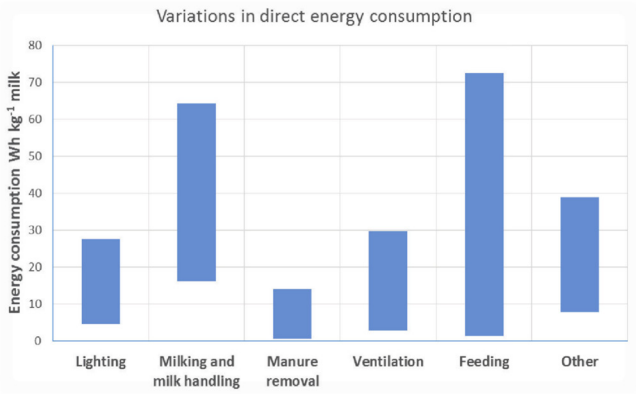

Fig 1. Direct energy consumption variation in milk production [24]

calculated into one lactating cow is equal to 800–1200 kWh in the USA and 401 kWh per lactating cow in Italy, 420 kWh in France and 90 kWh in Germany, respectively [31]. The estimates carried out by Bavarian State Research Centre for Agriculture indicate that electric energy consumption at dairy farm amounts to 640 kWh·year^{-1} as calculated per one cow whereas in the farms dealing with fattening of animals is lower and in the case of intensive fattening system, it is equal to 150 kWh·year^{-1} per one head of fattened cattle [18].

In the case of milk production, energy consumption may be classified into two categories, i.e. direct and indirect. The direct energy is intended directly for production in a form of electricity, gas or diesel oil. The indirect energy used, *inter alia*, in the manufacture of feeds, is mainly used in field work. The direct energy consumption for milk production is variable and is dependent on such factors as machines, production system, and the way of performing the work and the state of equipment management. The greatest direct energy consumers include lighting, milking and milk refrigeration, ventilation and feeding (Fig. 1) [24]. Feeding with 20–50% of energy consumption is indicated as the second most energy-consuming process at farm, immediately after milking [18, 31]. The energy consumption intended for feeding may be classified further according to the method of its utilization in 4 basic operations: transport from the warehouse, treatment of feed material (milling, disintegration), mixing and distribution [24].

At present, there are more than 20 producers of automatic feeding systems, i.e. the so-called feeding robots all over the world [30]. The systems of automatic feeding (AFS) may be differentiated according to the following classification: automatic distribution, semi-automatic and automatic feeding (Fig. 2) [18].

Until now, some analyses aiming at the definition of the method of functioning and energy consumption of automatic cattle feeding systems have been carried out. The obtained results may become the initial point of further considerations on justification or non-popularizing of the discussed solutions.

A study conducted at Bavarian farms [18] showed that the daily consumption of electric energy at AFS system varied between 8.8 kWh (semi-automatic system, Mixfeeder GEA/Mulerup) and 52.6 kWh (automatic system, Pellon). At the same time, it was revealed that the highest (77%) energy consumption was recorded in the case of process of transporting the raw materials from the storage site to the mixing unit and the mixing itself. Finally, the discussed analysis showed also that the costs of feeding the dairy cows with the employment of AFS (21.36–83.52 kWh ·LU-1 · year^{-1}) are lower as compared to the standard system composed of tractor and feeding wagon (4–6 moto hours · LU-1 · year^{-1}); 10 l ON · moto hours^{-1}). The authors of the present study notice also the possibility of employing solar energy as a power source

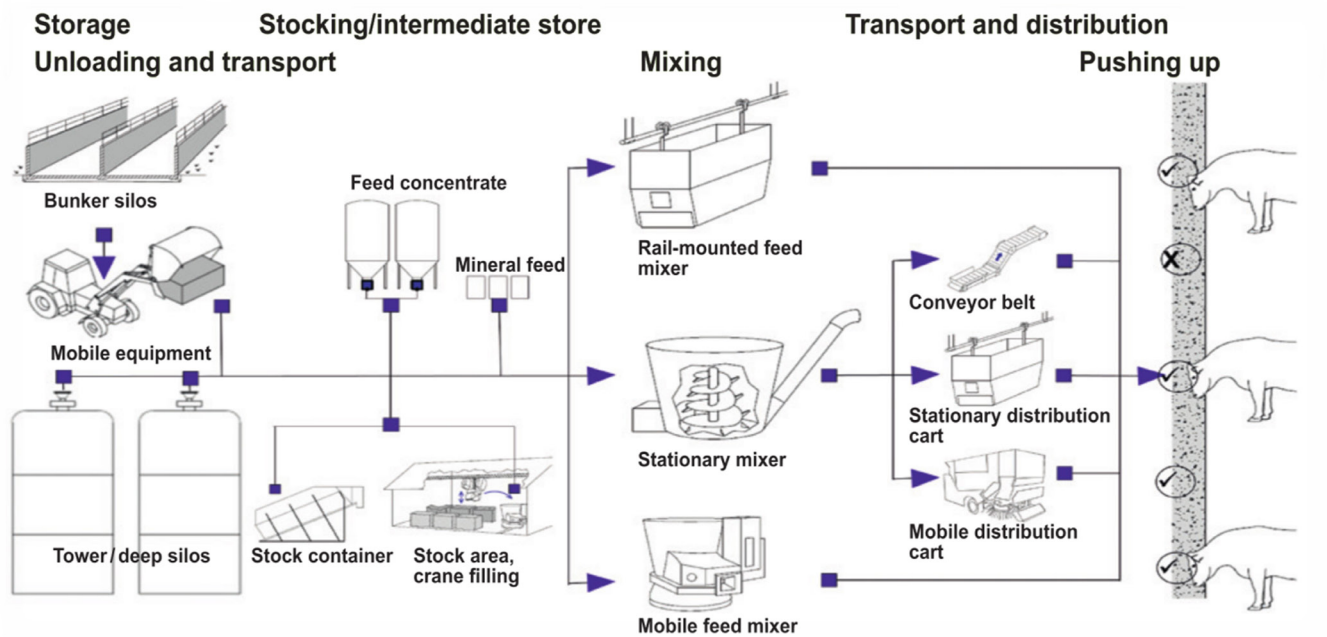

Fig 2. Techniques for realising various levels of automation in feeding (Haidn et al., 2014) [18]

Table 1. Daily consumption of energy and/or diesel oil and annual production of GHG depending on the cows' feeding method; the commercial brochure [14]

	Process	Daily electric energy (kWh) and/or diesel oil (l) consumption	CO_2 equivalent (ton · year-1)
Lely Vector (2 Mixing-Feeding Robots)	Filling the feed kitchen (every 2 days)	8,25 l	7,98
	Feed kitchen and Mixing-Feeding Robot (mixing and feeding)	37,50 kWh	7,35
Tailored Mixing Wagon (18m³)	Feeding (3 times per day)	45,00 l	43,52
	Feed pushing (6 times per day)	5,50 l	5,32
Self-propelled mixing wagon (20m³)	Feeding (3 times a day)	50,00 l	48,35
	Feed pushing (6 times per day)	5,50 l	5,32

** Comparison for 300 LU; Conversion to CO2 equivalent according to the guidelines of the German Federal Agency for Agriculture and Food; based on „Untersuchungen zum Elektroenergieverbrauch eines automatischen Fütterungssystems" Bühler J. (2017)*

for AFS system what lowers additionally the costs and is, simultaneously, the environment-friendly process.

The Italian studies [9] revealed that feeding of cows, using AFS (DeLaval Optimat Master) was less energy consuming than in the case of the conventional system composed of feeding wagon and tractor. In the herd consisting of 90 dairy cows with the mean milk yield amounting to 8 435 kg · year^{-1}, which received 10 m^3 TMR (total mean ration) per day, AFS system used 68.05 kWh · day^{-1} (including 2kg ON) whereas the conventional system (CFS, feeding wagon with capacity of 10 m^3 with a single vertical auger and tractor with power of 80 kW) used 246.64 kWh · day^{-1} what corresponded to 18.77 kg of diesel oil. Tangorra and Calcante [30] analysed utilization of energy (mixing and distribution of feed) at the Italian farm where AFS (Lely) replaced a classical set composed of feeding wagon (2 vertical augers, 30 m^3) being permanently combined with the agricultural tractor (110 kW). The compared equipment supplied feed to ca 490 cows per day (lactating and dry cows), delivering 19 000 kg TMR. The results of the discussed study revealed the mean energy consumption at the level of 40.2 ±2.3 kWh · day^{-1} what corresponded to 2.11 ±0.07· kWh·tonne-1 TMR in the case of automatic feeding system and daily energy demand equal to 1 387.62 kWh (assuming 11.86 kWh·kg^{-1} ON) in the case of CFS. In the discussed study, utilization of telescope charger was not considered due to the daytime of using the equipment which was the same in the both systems. In the opinion of the authors of the present paper, the further profits from the application of AFS system include the possibility of utilizing the renewable energy sources which allow, additionally, lowering the operating costs.

The illustrative comparison of the effect (emission of CO_2--equivalent) of automatic and conventional feeding system on the environment, as derived from the promotional materials of one of the producers of AFS system is given in Tab. 1 [14].

The Czech study [33] showed that the automatic cow feeding (Lely Vector) allows saving the feed. The conducted experiment revealed that the cows fed under the AFS system received feed in the quantity of 43.2 kg · cow^{-1} and in the conventional system (feeding cart Cernin 13 m^3 and tractor with power of 64 kWh) – 46.6 kg · cow^{-1}. In spite of the fact that the amount of the feed, supplied by the automatic system was lower, its real intake was increased because in the case of Lely Vector equipment, the losses in feed were equal to ca. 5% whereas in the case of CFS, they exceeded 10%. Besides it, the quantity of milk, produced by the cows at total lower amount of the supplied feed remained unchanged or was higher. The discussed statements are consistent with the Finnish reports [16] indicating that more frequent feed supply (5 times vs. once) during a day (24 h) was more favourable for better utilization of energy and protein. The discussed study revealed that more frequently fed cows consumed 1 kg DM less (20.9 vs. 19.9 kg a day) without any significant effect on their milk performance.

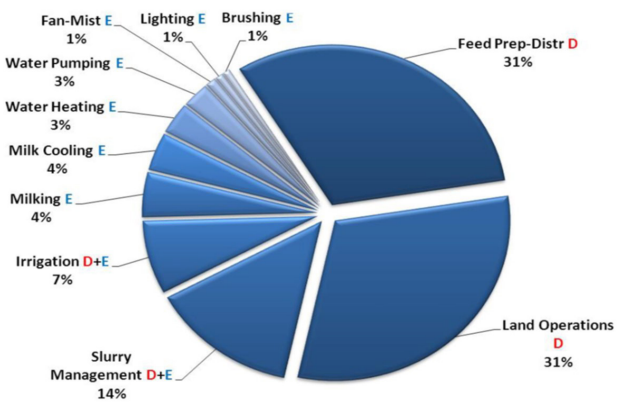

Fig 3. Distribution of GHG emissions from electricity (E) and diesel (D) to on-farm operations [31]

Apart from the lower energy consumption and lower operating costs of the automatic systems, we should also pay attention to the profits, resulting from the increase of the frequency of feeding. The increase of their number e.g. from 1 to 4 may affect positively the animal welfare by, *inter alia*, lowering of the competition at feeding table. Besides it, the authors of the available respective papers emphasize the possibility of utilizing such energy sources as biogas or photovoltaic panels for operation of automatic feeding systems [8, 19].

Summing up

Low-carbon agriculture is characterized by a low energy consumption, low emissivity and high effectiveness [24]. Reaching the mentioned targets, with the simultaneous mitigation of negative impacts of milk production on the environment is possible. We should however remember that the lactating cows and heifers are the main sources of greenhouse gas emission at the dairy farms (intrasystemic fermentation, manure). The remaining factors such as electricity, soil fertilization, transport and application of manure have a smaller meaning [6]. Due the mentioned reasons, the breeders should focus their attention on practices, connected with the herd management; the undertaken activities should consider ensuring more efficient feeding and constant improvement of genetic animal breeding in order to obtain the animals characterized by better feed conversion for milk production. The healthy animals, revealing a high resistance to diseases, are the key factors of the milk performance of the whole herd. We should also bear in mind the practices, serving the improvement of the key reproduction indicators such as calving percentage rate or the age of the first calving [6, 26, 35]. The undertaken measures should also consider the modification of manufacturing processes, oriented to those ones, characterized by a lower energy demand, lower quantity of the wasted products, and introduction of the environment–friendly and more effective practices in animal husbandry [26, 35]. The Lithuanian researches [5] indicate the extension of the knowledge on animal feeding among the breeders as the important solution; they also pay attention to the application of automatic feeding systems, connected with the milking robots which allow increasing the possibilities of controlling the nutritive value of the supplied concentrates at the level of the particular cows.

When bearing in mind information on lower energy consumption in the case of automatic feeding systems, operated by electric energy and ensuring better feed utilization, it seems that AFS may contribute to lowering of carbon footprint, generated by the dairy farms. At the same time, the determination of the real scale of their effect, taking into consideration a lot of relations and indirect effects of the employed feeding practices (health state, productivity of animals, fertility, welfare, demand on home produced feeds, etc.) is not easy to be estimated and requires further attempts aiming at its determination.

The other problems, connected with automation of animal feeding include the economic aspects. It is commonly known that the automatic feeding systems are superior in respect of the costs in comparison to the conventional systems at the stage of investments. On the other hand, it is worthy to examine the long-term, financial consequences of employing the discussed type of instruments, with the consideration of the profits and direct and indirect costs as well as the mentioned relationships in the context of the natural environment protection.

Bibliography

[1] Battini F., Tabaglio V., Amaducci S. 2016, Environmental impacts of different dairy farming systems in the Po Valley, Journal of Cleaner Production, 112, s. 91–10

[2] Baumann D.E., Capper J.L.. Efficiency of dairy production and its carbon footprint. https://animal.ifas.ufl.edu/apps/dairymedia/rns/2010/11-Bauman.pdf, accessible on 30.06.2021

[3] Bava L., Tamburini A. Penati C., Riva E., Mattachini G., Provolo G., Sandrucci A. 2012, Effects of feeding frequency and environmental conditions on dry matter intake, milk yield and behaviour of dairy cows milked in conventional or automatic milking system, Italian Journal of Animal Science, 11(e42), s. 230–235

[4] Bieńkowski J., Baum R., Holka M. 2021, Eco-efficiency of milk production in Poland using the life cycle assessment methodologies, European Research Studies Journal, XXIV, 1, s. 890–912

[5] Brizga J., Kurppa S., Heusala H. 2021, Environmental impacts of milking cows in Latvia, Sustainability, 13, 784

[6] Capper J.L., Cady R.A. 2020, The effetcs of improved performance in the U.S. dairy cattle industry on environmental impacts between 2007 and 2017, Journal of Animal Science, 98(1), s. 1–14

[7] Cutress D. 2020, Can precision farming help mitigate climate change?, Farming Connect, s. 1-8, https://pure.aber.ac.uk/portal/files/37585832/Precision_farming_ technologies_and_ climate_change_mitigation.pdf, accessible on 26.05.2021

[8] Da Borso F., Chiumenti A., Sigura M., Pezzuolo A. 2017, Influence] of automatic feeding systems on design and management of dairy farms, Journal of Agricultural Engineering, XLVIII(s1): 642, s. 48–52

[9] Guerci M., Bava L., Zucali M., Sandrucci A., Penati C., Tamburini A., 2013, Effect of farming strategies on environmental impact of intensive dairy farms in Italy, Journal of Dairy Research, 80, s. 300–308

[10] Hosseinzadeh-Bandbafa H., Safarzadfeh D., Ahmadi E., Nabavi Pelesaraei A. 2016, Modeling output energy and greenhouse gas emission of dairy farms using adaptive neural fuzzy inference system, Agricultural Communications , 4(2), s. 14–23

[11] Johnston C., DeVries T.J. 2018, Short communication: Associations of feeding behavior and milk production in dairy cows, Journal of Dairy Science, 101, s. 3367–3373

[12] Karbowy A., Koniuszy A., Sędłak P. 2012, Assessment of average exhaust emissions from a farm tractor operating in a livestock building, TEKA. Commission of motorization and energetics in agriculture, 12(1), s. 69–72

[13] Kilic I., Yayli B. 2020, Environmantal sustainability in livestock farms [w:] KUTER B., KESKIN N., Agricultural and natural science. Theory, current researches and new trends, ISBN: 978-9940-46-038-9, s. 73–92

[14] Lely 2020, https://www.lely.com/media/lely-centers-files/brochures/published/Lely _Flyer_Energief%C3%B6rderung_web.pdf, accessible on 20.07.2021

[15] Lioy R., Dusseldorf T., Meier A., Reding R., Turmes S., 2014, Carbon footprint and Energy consumption of Luxemburgish dairy

farms, http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2014/WS_2_7_Lioy.pdf, accessible on 12.07.2021
[16] Mantysaari P., Khalili H., Sariola J. 2006, Effect of feeding frequency of a total mixed ration on the performance high-yielding dairy cows, Journal of dairy Science, 89, s. 4312–4320
[17] Mielcarek P., Rzeźnik W. 2018, Greenhouse gas emission from Polish agriculture in the years 2007–2016, Proceedings of 17th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 23–25 May, 2018, s. 1754-1759
[18] Oberschatzl R., Haidn B., Neiber J., Neser S. 2015, Automatic feeding systems for cattle – A study of the energy consumption, Proceedings of XXXIX CIOSTA & CIGR V International Conference, St. Petersburg, Rosja, 26–28 Maj 2015
[19] Pezzulolo A., Chiumenti A., Sartori L., Da Borso F. 2016, Automatic feeding system: Evaluation of energy consumption and labour requirement in north-east Italy dairy farm, Proceedings of 15th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 25-27 May, 2016, s. 882–887
[20] Piwowar A. 2019, Low-carbon agriculture in Poland: Theoretical and practical changes, Polish Journal of Environmental Studies, 28(4), s. 2785–2792
[21] Podkówka Z., Cermak B., Podkówka W., Broucek J. 2015, Greenhouse gas emissions from cattle, Ekologia, 34(1), s. 82–88
[22] Prasard R.J., Sourie S.J., Cherukuri V.R., Fita L., Merera C.E., 2015, Global warming: Genesis, facts and impacts on livestock farming and mitigation strategies. International Journal of Agriculture Innovations and Research, 3, s. 1494–1503
[23] Preethika D.D.P., Wadanambi R.T., Wandana L.S., Chathumini K.K.G.L., Dassanayake N.P., Udara S.P.R. 2021, Energy management contribution for greenhouse gas mitigation, Journal of Research Technology and Engineering, 2(2), s.1–13
[24] Rajaniemi M., Turunen M., Ahokas J. 2015, Direct Energy consumption and savings possibilities in milk production, Agronomy Research, 13(1), s. 261–268
[25] Rotz C.A. 2014. Impact of increasing milk production on whole farm environmental management. Proceedings of the 12th Annual Mid-Atlantic Conference, s. 39–44.
[26] Sarkwa F.O., Timpong-Jones E.C., Assuming-Bedikao N., Aikins S., Adogla-Bessa T. 2016, The contribution of livestock production to climate change: a review, Livestock Research for Rural Development, 28, Artykuł #37
[27] Scott A., Blanchard R. 2021, The role of anaerobic digestion in reducing dairy farm greenhouse gas emission, Sustainability, 13, 2612
[28] Shine P., Breen M., Upton J., O'Donovan A., Murphy M.D. 2019, A decision support system for Energy use on dairy farms, Proceedings of the Precision Livestock Farming '19 Conference, s.45–52
[29] Sniffen C.J., Chalupa W. 2015, Targeted feeding to save nutrients, Western Dairy Management Conference, Reno, NV, 03-05.03.2015
[30] Tangorra F.M., Calcante A. 2018, Energy consumption and technical-economic analysis of an automatic feeding system for dairy farm: Results from a field test, Journal of Agricultural Engineering, XLIX(869), s. 228–232
[31] Todde G., Murgia L., Caira M., Pazzona A. 2018, A comprehensive Energy analysis and related carbon footprint of dairy farms, part 1: Direct Energy requirements, Energies, 11(451), s. 1–14
[32] Trupa A., Aplocina E., Degola L., 2015, Forage quality and feed intake effect on methane emission from dairy farming, Proceedings of 14th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 20-22 May, 2015, s. 601–605
[33] Vaculik P., Smjetkova A. 2019, Assessment of selected parameters of automatic and conventional equipment used in cattle feeding, Agronomy Research 17(3), s. 897-889
[34] Wisniewski P., Kistowski M. 2019, Local-level agricultural greenhouse gas emission in Poland, Fresenius Environmental Bulletin, 28(3), s. 2255–2268
[35] Zifei L. 2015. Carbon footprint of livestock production, https://bookstore.ksre.ksu.edu/pubs/MF3180.pdf, accessible on 30.06.2021

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PACKAGING MARKET IN POLAND

RYNEK OPAKOWAŃ W POLSCE

Summary: *Since the ancient times, packaging played an important role in human life. The people had to find the solutions in order to store the products such as cereal grains or food. Their task was additionally difficult due to the lack of technical novelties which are known nowadays. At present, the packages found in the shop shelves are much more functional and facilitate life of their users. They serve not only for a safe accumulation of foods and drinks but they have also become a marketing element or information carrier; their constructions have a great meaning in transport and storage. The contemporary packaging should be sufficiently innovative, attractive and distinctive as to focus the attention of the consumer. It has a great meaning due to the fact of incidence of a very big variety of goods on the market. Additionally, each package is expected to possess different forms and properties. We require something different from the packaging for food products; other elements are important for cosmetics, or for the users of medicine products or household chemicals.*

Food industry, which needs packaging for food and drinks, is the vastest sector of packaging market in Poland. It causes that this sector embraces a wide spectrum of innovations, the task of which will be maintenance of the product's freshness. The successive branch of the discussed sector includes household packages; their producers compete in the ideas of more and more innovative, convenient and, first of all, safe packages. The cosmetic industry is more tolerant in respect of durability of the products but it is also developing and is focused on facilitation of use of the products by the customers. On the other hand, pharmaceutical industry is concentrated on safe packaging, being non-available for the children and protected from adulteration.

The purpose of the present paper is to discuss the types and basic functions of the packaging in the particular industrial sectors as well as to show the direction of the development of the particular branches in the packaging sector. The approximate structure of packaging market in Poland was also described.

Keywords: *types of packaging, functions of packaging, classification of packaging, packaging market, characteristics of packaging sector*

Streszczenie: *Opakowania już od czasów starożytnych pełniły ważną rolę w życiu człowieka. Ludzie musieli znaleźć rozwiązania, aby przechowywać produkty takie jak ziarna zbóż czy żywność. Ich zadanie było dodatkowo utrudnione ze względu na brak nowinek technicznych, które znane są obecnie. W dzisiejszych czasach opakowania na sklepowych półkach są o wiele bardziej funkcjonalne i coraz bardziej ułatwiają życie ich użytkownikom. Służą nie tylko do bezpiecznego gromadzenia jedzenia i picia, ale bywają też elementem marketingowym, nośnikiem informacji, a ich konstrukcje mają duże znaczenie przy transporcie i magazynowaniu. Obecne opakowanie powinno być wystarczająco innowacyjne, atrakcyjne oraz wyróżniające się, aby skupić na sobie uwagę konsumenta. Ma to ogromne znaczenie ze względu na fakt występowania tak wielkiej różnorodności towarów na rynku. Dodatkowo, od każdego opakowania oczekuje się innych aspektów i cech. Czego innego będzie się wymagać od opakowań dla produktów spożywczych, co inne będzie ważne dla kosmetyków, na czym innym zaś będą się skupiać odbiorcy opakowań leków czy chemii gospodarczej.*

Przemysł spożywczy potrzebujący opakowań do żywności i napojów jest najbardziej rozległym sektorem rynku opakowaniowego w Polsce, co sprawia, że obecna w nim jest szeroka gama innowacji, których zadaniem będzie utrzymanie świeżości produktu. Kolejną gałęzią tej branży są opakowania gospodarcze i tu producenci również prześcigają się w pomysłach na coraz to bardziej innowacyjne, wygodne, a przede wszystkim bezpieczne opakowania. Przemysł kosmetyczny z kolei jest bardziej tolerancyjny w kwestii trwałości kosmetyku, ale również się rozwija i skupia się na ułatwianiu użytkownikom korzystania z produktów. Farmacja natomiast koncentruje się na opakowaniach bezpiecznych, niedostępnych dla dzieci oraz zabezpieczonych przed podrobieniem.

Celem niniejszego artykułu jest przedstawienie rodzajów i podstawowych funkcji opakowań w różnych gałęziach przemysłu, a także zaprezentowanie kierunków rozwoju poszczególnych sektorów branży opakowaniowej. Opisano w nim również przybliżoną strukturę rynku opakowaniowego w Polsce.

Słowa kluczowe: *rodzaje opakowań, funkcje opakowań, klasyfikacja opakowań, rynek opakowaniowy, charakterystyka rynku opakowań*

Types and functions of packaging

The contemporary market tempts the consumers with the products in diverse coloured packages, printed with the whole palette of colours, with more and more original shapes, closures etc. Such packages play often a meaningful role in the process of encouraging the customers to buy the products, packed in the mentioned materials. They play also many other functions which will be described below. To understand the essence of packaging, we should additionally consider their role and classify them respectively; it will be discussed in the further parts of the present paper.

The idea of package and its functions

According to the definition from Vocabulary of Polish Language (in Polish: Słownik Języka Polskiego, PWN) package is called everything which a given thing is wrapped in, sometimes together with the content [1]. Encyclopaedia of PWN (Polish Scientific Publishing House) describes it as an object (set of objects) or material protecting a product from a loss (caused by its destruction e.g. by insects, rodents, rain etc), theft and the change in its quality during transport, storage and exposure or use by the customer [1]. The packages have also their definition, submitted in PN-O-79000:97 Packaging. Terminology. Accord-

ing to the mentioned document, it is the article which ensures maintenance of a defined quality of the packaged products, their adaptation to transport and storage and exposition, as well it protects the environment from harmful impacts [5]. The packaging is not contained, therefore, in one definition; so, it may be concluded that it plays many functions.

Functions of packages may be classified as follows:

- Primary, connected with transport, protection and identification of the package's content;
- Secondary, such as logistics, marketing, ergonomics and ecology [3]

The basic aim of the package is ensuring the barrier between the product to be packed and the environment. It should be relatively resistant to mechanical factors, being understood as all types of shocks, strokes, overloads and loading etc. It is especially important function at transport of packages and their storage. The packed product should not be affected by any physicochemical factors such as ambient temperature, air humidity, light, biological threats or gases present in the air and, in particular, oxygen and carbon dioxide. Otherwise, the quality of the product may be deteriorated what leads to its low yield, quicker deterioration i.e. wastage or even threat to health or life of it user. The package protects also the environment and the user from the product itself, inter alia, from corrosive, toxic and strongly odorous substances etc.

The successive significant function of packaging is to identify its contents. Apart from aesthetic impressions, a given package should contain basic information on the product which is found inside it. The mentioned information should be clearly submitted to the user of food product packages. The obligatory labelling is specified in the Regulation of the European Parliament and of the Council (EU) 1169/2011 of 25 October 2011 on the provision of food information to consumers [4]. It includes the following information:

- name of food;
- the constituents present in the food;
- data of durability or expiration date;
- the method of production or application, especially in the case when a lack of such information could cause improper proceeding with a food;
- the data, indentifying a natural person, legal person or organizational unit, not possessing the legal personality, which produces or packs the food products or introduced the food products to sale if the activity in this respect is registered at the territory of any Member State of the European Union, or at the territory of the member State of EFTA (European Free Trade Agreement), being the side of the Agreement of the European Economic Area (EEA), and the place or source of origin in the case when a lack of such information could mislead the consumer;
- net content or the number of pieces of the packed food;
- the storage conditions when the label on the packaging of the food contains information on the expiration date of the product, and in the case when the quality of the food is significantly dependent on the conditions of its storage;
- marking of production lot, understood as a defined quantity of food product, manufactured, processed or packaged practically under the same conditions;
- grade of the trade quality if it was established in the rules concerning particular requirements in respect of trade quality of agri-food products or their groups, or another discriminant of trade quality if the obligation to present the mentioned feature is resulting from the separate regulations.

As it is followed from the above presentation, there is a lot of such information.

Classification of packaging

The packaging market is differentiated in respect of the products which constitute the discussed branch. According to the definition, package is called everything, which a given thing is wrapped in. It may refer to the product covered with the brand tape in such a way that all its elements are connected together as well as to a beautiful pack of chocolates in a sophisticated box made of texture, with a complicated construction. It shows that the discussed products may be diversified very much. We may state that a simple and uniform classification, considering a single property of package is not possible.

One of the most important classifications of the packaging includes the following division:

- Unit package,
- Collective packaging
- Transport (outer) packaging

We call **unit package** as a package destined for a defined quantity of product, intended for retail sale. It plays a protective and informational-promoting function [5]. The **collective package** contains at least two unit packages and they are usually employed in transport and storage. Similar application is used in the case of **transport packages** which join collective packages in order to facilitate the handling processes. The discussed packages may constitute only wrapping but they may also reveal the specified construction. They may contain auxiliary elements such as grids, tapes, inserts or labels.

Another classification is connected with the **type of material** from which a package is made. The packages may be produced from the following materials:

• uniform (homogenous) such as:

- paper and cardboard;
- plastics,
- metal,
- glass,
- wood,
- ceramics,
- textiles.

• multilayer, otherwise being called composite, obtained from the following materials:

- metals,
- various plastics.

Together with the type of material from which a given package was produced, there is also the possibility to classify the dis-

cussed products due to a **stiffness** of material. We can distinguish the following packages:

— soft, made e.g. from textiles or paper;
— flexible, produced from film and from laminates;
— stiff, such as cardboard, wood, glass or made of harder plastics.

The packages may be also classified in respect of their **constructional form**. We may divide them as it follows:

— cardboard boxes,
— bottles,
— cases,
— packs,
— containers,
— cans,
— baskets,
— buckets,
— ampoules,
— small jars,
— tubes,
— bags,
— other ones, being present at the market.

Due to the fact that constructions of packaging are differentiated, we may also distinguish another division according to their **susceptibility to folding and unfolding**. Therefore, the package may be:

— stiff and not demountable,
— folded which may be unfolded without separation of its elements
— foldable as nest, where one package may be inserted into another one.

The packages may be also distinguished due to their special processes and functions and namely:

— with a modified atmosphere
— vacuum,
— heat-shrinkable,
— active.

Another classification of packages is as it follows:

— range of sale, i.e. domestic or export market,
— frequency of use, i.e. single-use or reusable,
— form of accounting, treated as sold or returnable,
— relation with a product, i.e. direct or indirect.

Packaging may be also divided according to their **destination**. Food products have a different construction of packages as compared to packages for cosmetics. Pharmaceutical and industrial packaging has also different structure, form and material.

Packaging market

In order to describe the structure of the packaging market, we should, first of all, define the idea of "market" itself. From the economic viewpoint, the market includes the whole process of transactions of purchase and sale and the conditions under which the mentioned processes run [III]. The packaging market is measured by the value of the sold packages and is focused on the space where the settlement shops as well as the markets, trade centres and similar objects are functioning together. It refers also to on-line dispatch of goods. Before it is found at the consumer, the packaging must pass the whole route of the supply chain. Hence, we can distinguish the ideas: "the user of packaging" and "the consumer". The first phrase refers to many persons who have the contact with a given package and the second idea is only a final element of the total way of the products – from the moment of its manufacture, packing until the meeting with the consumer. At the beginning, its first user is the producer of the package who introduced the packaging to circulation. The successive stages are as follows:

— passage through the logistics centres and big warehouses where the labelling of the product will be significant for the users of the packages,
— easiness of finding it out on the shelf;
— durability of the packaging;
— resistance to the transport conditions;
— adaptation to loading and unloading operations etc.

The successive point in the discussed process includes stores, small shops, bazaars and similar objects where the employees are able to evaluate the easiness of distributing the products on the shelves. It has to be assessed whether the packages have a simple construction, how much space they occupy on the shelf, whether are stable and so on. The employed persons may also notify the defects of packaging.

In the situation when the packed product is already found at the consumer, there is also the possibility to evaluate the package from all sides during its real use, that is:

— whether use of the package is convenient;
— whether it is readable, hermetic and aesthetic,
— whether it fits in the fridge etc.

During the recent period, there has arisen the question whether it is possible to use the packaging again and how it can be processed. It results from the ecological trends, care of the Planet and environment and also, from the respective legal regulations.

The contemporary packaging sector is oriented to care of environment, reduction of waste, increase of functionality of packaging and durability of the products, especially of foods. There are introduced more and more available innovative solutions which, for example, provide information on durability and freshness of the product inside the package.

Characteristics of packaging market

The market of packaging is developing in dependence on economic development and increase of the wealth of the society [2]. In the situation when the inhabitants of a given country are wealthy and can afford purchase of more goods, they buy and use more. Export of products abroad is the second factor, affecting the development of a given sector.

In Poland, a dynamic improvement of the packaging market situation occurred and the transformation of the system was carried out. The previous system was characterized by greyness, empty shelves; so, it was then more important for the people

that they could buy a given product at all than the fact whether it possessed any packaging. For example, nobody was surprised in the past when the meat or fish were packed in the newspapers. Fruits and vegetables were packed in woven bags and milk was delivered in the morning at the door in glass bottles; it was also sold in a foil bag. The packages such as cans or glass were reusable as they could be changed instead of other hardly available basic products. In Polish People's Republic there was no place for diversified, aesthetic packages, attracting the attention of the consumer. We may say that the packaging industry did not practically exist in the discussed period [IV]. The PEWEX (payment in foreign currency) shops were the exception – they sold the foreign goods which – in the contrary to the domestic products – were colourful and attractive. In 1989, after the transformation of the system and passage from the centrally planned economy into the market oriented one, production and sale of packaging increased very quickly. In 2018, according to the data of Polish Chamber of Packaging, the value of packaging market was equal to ca. 10.4 billion EUR i.e. more than 44 billion PLN. At present, production of packaging materials in Poland (according the studies of the Association of Employers of Cardboard Producers and Suppliers, ECMA) is increased by ca. 7% each year. According to the prognoses for 2020 – the average Pole used packages with the total value approximating 300 EUR annually [IV]. The forecasts and analyses show that value of packaging market in Poland in 29025 will reach 13 billion EUR, that is about 55 billion PLN and the consumption of packages, as calculated per one inhabitant will be equal to ca. 340 EUR. According to the data of the Main Statistical Office (GUS) about 8 thousand entities produced packaging in Poland in 2018. They were mainly small companies where no more than 10–15 persons were employed whereas the number of the persons employed in the total packaging industry was equal to ca. 230 thousand persons. Polish packaging market produces about 6 million tonnes of packages annually what gives ca. 157 kg per one inhabitant [VI].

According to the data of GUS of 2018, the total value of Polish packaging market amounted to 10.4 billion EUR, that is, 44.2 billion PLN; it was by 7% increased as compared to the previous year what is the result better than in the world market. The mentioned result was affected by the increase of consumption and export. In 2018, the experts of the Polish Chamber of Packaging forecasted a decline of the growth indicators in the packaging market. The data concerning the values of the packaging market are given in Tab. 1.

Table 1. Packaging market in Poland in the years 2017-2025 [V]

Year	2017	2018	2019	2020	2025
Total value of market [in billion EUR]	9.8	10.4	11.0	11.4	13.0
Consumption of packages per one inhabitant [EURO]	257.0	274.0	289.0	300.0	340.0

The packaging market is constantly dominated by plastic packages. They consist, in turn, of a half (more or less) of flexible packages such as bags, foils, laminates and of stiff packages, i.e. bottles and boxes. The plastic packaging market is divided into 4 segments shown in Fig. 1, together with their percentage participation and namely:

- flexible materials and packages, ca. 46%;
- thermoformed plastic packages, ca. 9.5%;
- packages, formed by the blow method, ca. 31%,
- packages formed by injection moulding, ca. 13% [1].

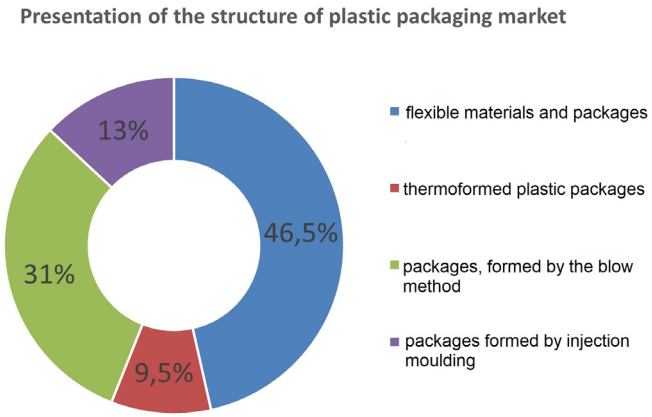

Fig. 1. Presentation of plastic packaging market [1]

According to the prognoses of Polish Chamber of Packaging of 2018, the packages made from paper and cardboard in 2025 will become equal to plastic packages in respect of the percentage participation. Production of plastic packaging will be decreasing and that one of paper and cardboard will be increased. It results, *inter alia*, from the ecological tendencies present at the market. On the other hand, metal packaging constituted 11.6%, glass packages – 9.8%, those made of wood and others – 5.6%. The structure of packaging market according to material used for its manufacture is given in Tab. 2.

Table 2. Structure of packaging market in Poland according to packaging material. Situation in 2018, prognoses for the years 2019–2025, in % [V]

Consumption [%]	Years			
Material	2018	2019	2020	2025
Plastics	37.8	37.5	37.3	37.0
Paper and cardboard	35.2	35.8	36.4	37.0
Metal	11.6	11.4	11.2	11.0
Glass	9.8	9.6	9.3	9.0
Wood and others	5.6	5.7	5.8	6.0

Tab. 3 illustrates the percentage distribution of packaging participation in the market according to their destination. The

packaging for food and drinks constitute almost 65%. The mentioned sector reveals, however, a declining tendency what is connected with the development of trade, consisting in the purchase of food "without packaging" such as loose grits, pastes, delicacies, fruits, vegetables, etc. The quality of drinking water has been recently improved, so more and more persons choose such solutions as jars and bottles with filter which allows drinking a tap water. The mentioned ecological trend causes, simultaneously, a decrease of demand on PET bottled water. More and more frequently, we begin to speak about recycling automatic machines present at Polish streets; the people bring their own boxes to milk bars and eating houses in order not to use the single-use packages from a given place. In the "bio" shops, we may – at the additional payment, of course – pour a squeezed juice directly to own bottles.

Table 3. Structure of packaging market in Poland according to destination of the package, Situation in 2018, prognoses for the years 2019–2025, in % [V]]

Participation[%]	Years			
Destination of packages	**2018**	**2019**	**2020**	**2025**
Food	48.0	47.8	47.5	46.0
Drinks	15.0	14.7	14.5	13.5
Industrial products	26.0	26.2	26.3	27.0
Pharmacy	6.0	6.2	6.4	7.5
Cosmetics	5.0	5.1	5.3	6.0

In 2020, the world market was subjected to enormous changes, as affected by coronavirus pandemic and the restrictions, employed in majority of the countries; it included closure of the particular sectors such as gastronomy or hotel industry. The sale of takeaway food has been increased; owing to this fact, the people could see the important role of packages. In connection with the above, the sales of packaging for food industry increased by ca. 10-12%, for pharmaceutical industry – by ca. 3% and for sector of cosmetics and personal hygiene agents such as antibacterial gels or surgeon masks – by ca. 2%. At the same time, as a result of restrictions and closing of shops, a decline in the sale of packaging for industrial goods, furniture, home devices by AGD, RTV, household chemicals etc., was recorded. Pandemic caused also popularization of on-line trade, therefore, there was increased the manufacture of cardboard packages in which the customers received their ordered goods. According to the studies of Mondi company and of Karmasin Research & Identity Institute [VII], almost 45% respondents increased their frequency of buying by Internet as compared to the stationary purchases. It is estimated that, in the future, 86% of new customers will take advantage of such form of trade. It was also revealed that apart from a durable package owing to which the consignment will not be damaged, 80% of the respondents were interested very much whether a given package was sustainable and environment-friendly; 57% of the persons belonging to the mentioned above group would be ready to pay more for the delivery ensuring optimum protection of the contents, simplicity of service, and being produced from organic material. It is therefore estimated that production of packaging paper such as paper bags, or packages made from solid cardboard and corrugated cardboard was increased by 2% as compared to 2019 [VIII]. What is interesting, according to British NOA[1] Ltd company, in spite of the increased on-line sale during pandemic, the global demand on corrugated packaging, especially in gastronomic sector was decreased whereas it was increased for the suppliers of food and drinks who delivered the mentioned above products to retail trade [IX]. According to NOA report, production of corrugated packaging in Great Britain, and the USA decreased by 0.5%, in France and Italy – by 5 – 10% and in such countries as Mexico or Argentina, the decline of production reached two-digit percentage values. On the other hand, the producers of food and drinks recorded the increase of demand by 120%. Such discrepancies in similar sectors result, *inter alia*, from regional and culture differences at a given area.

References

[1] Wasiak W. i inni, Przemysł Opakowań w Polsce. Stan. Perspektywy. Oferta. 2012. Monografia, Polska Izba Opakowań, Warszawa, 2012
[2] Wasiak W. i inni, Kierunki rozwoju opakowań. Wybrane problemy. Monografia., Warszawa, 2014
[3] Szymczak J., Ankiel-Homa M. Opakowanie jednostkowe w działaniach marketingowych przedsiębiorstw, Wydawnictwo Akademii Ekonomicznej, Poznań 2007
[4] Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 10 lipca 2007 r. w sprawie znakowania środków spożywczych
[5] PN- O- 79000:97 Opakowania. Terminologia
[I] https://sjp.pwn.pl/sjp/opakowanie;2495378
[II] https://encyklopedia.pwn.pl/haslo/opakowanie;3951217.html
[III] https://pl.wikipedia.org/wiki/Rynek_(ekonomia)
[IV] https://wyborcza.pl/1,155287,20876958,w-prl-ta-branza-nie-istniala-teraz-jest-warta-4-6-mld-zl-opakowania.html
[V] https://www.rynekpapierniczy.pl/artykul/dobre-prognozy-dla-rynku-opakowan-w-polsce-2107
[VI] https://etisoftpackaging.pl/rewolucja-opakowan-polscy-producenci-wobec-zmian/
[VII] https://www.mondigroup.com/en/newsroom/press-release/2020/increase-in-online-shopping-across-central-and-eastern-europe-is-here-to-stay-but-it-must-be-green/
[VIII] https://www.rynekpapierniczy.pl/artykul/rynek-papierow-higienicznych-i-opakowaniowych-w-dobie-covid-19-2814
[IX] https://noa.uk.net/impact-of-covid-on-packaging-food-suppliers-flourish-while-demand-for-srp-is-set-to-fall/.

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THE CONCEPT OF A PROCONSUMER HYDRO POWER PLANT WITH A SPECIAL BEARING FOR THE MAIN SHAFT

KONCEPCJA PROSUMENCKIEJ SIŁOWNI WODNEJ ZE SPECJALNYM ŁOŻYSKOWANIEM WAŁU GŁÓWNEGO

Summary: *This paper presents the idea of economical, proconsumer hydro power unit. The described hydro power unit allows the generating of electric energy for own needs. However, the overproduction of power can be supplied to the state energy system.*
The hydropower units of small output that use the local rivers and creeks should additionally support the operation of wind power units. The design of such units should consider such restriction as, among others, cyclic operation that is characterized by often starts and stops.
Proconsumer hydropower units have to assure a fast start, respective energy efficiency and a very high durability. These features can be obtained by means of proper design of the journal bearing of turbine main shaft. Hybrid bearing system connecting the journal bearing with the rolling bearing assures the decrease in the start power losses, good durability and reliability of proposed system of hydropower unit. Very important feature of this system is the application of the rolling bearing during the operation. Such bearing allows
the decrease in the start time and protects against an insufficient load capacity of lubricating oil film. It is possible to apply the emulsions oil-water as well as clean water as lubricant, too.

Keywords: *substrates, proconsumer hydropower unit, combined rolling-journal bearing system*

Streszczenie: *Artykuł przedstawia koncepcję ekonomicznej, prosumenckiej siłowni wodnej. Omówiona energetykę prosumencka pozwala użytkownikom na wytwarzanie energii elektrycznej na własne potrzeby. Przewidziano możliwość przekazywania nadmiaru energii do krajowej sieci energetycznej.*

Uzupełnieniem wiatrowej energetyki prosumenckiej może być wykorzystanie małych siłowni wodnych wykorzystujących lokalne zasoby rzek i strumieni. Konstrukcja siłowni wodnych dla indywidualnych potrzeb uwzględnia szereg ograniczeń w tym okresową pracę charakteryzującą się częstymi rozruchami i zatrzymaniami.

Prosumenckie siłownie wodne muszą zapewniać szybki rozruch, odpowiednią sprawność energetyczną oraz wysoką niezawodność. Cechy te może zapewnić odpowiednie rozwiązanie łożyska ślizgowego wału głównego. Hybrydowy układ łożyskowania łączący łożyskowanie ślizgowe z tocznym zapewnia zmniejszenie oporów rozruchowych, trwałość i niezawodność proponowanego układu siłowni wodnej. Ważną cechą proponowanego rozwiązania konstrukcyjnego jest zastosowanie wspomagającego łożyska tocznego, które automatycznie włączane jest do pracy podczas wybiegu. Łożysko toczne zapewnia zmniejszenie czasu rozruchu i zabezpiecza przed pracą w warunkach niedostatecznej nośności filmu smarowego. Możliwe jest również zastosowanie emulsji olejowo-wodnych i czystej wody.

Słowa kluczowe: *prosumencka energetyka wodna, łożyskowanie ślizgowo-toczne*

Introduction

Proconsumer energy, where users themselves generate electricity for their own needs, and possibly sell excess energy to the general grid, in Polish conditions, may be based on the use of wind and water energy. Wind conditions in most of the country, except for the coastal zone and hills, conditions are limited, and there are often virtually windless periods [1]. In low winds, when the proconsumer wind turbines stop, the tall "windmills" are still able to work.

A supplement to proconsumer energy can be the use of small water power plants (units) using local resources of rivers and streams. Due to the lowland location, the available drops in local waters are generally small, and there are often water shortages. Hence, the design of hydroelectric power stations for the purposes of individual use must take into account a number of limitations. In particular, small hydropower units can operate periodically intermittently, which forces frequent start-ups and shutdowns of the systems.

Design solutions of such hydro power units must ensure quick start-up with low starting resistances, good energy efficiency, and high reliability and facilitated ongoing service by the users themselves of energy obtained from a proconsumer installation. The costs of a hydropower unit for individual use, when the investors are direct users, are very important.

The concept of a small hydropower unit operating in conditions of frequent starts and shutdowns

Unlike industrial hydropower, special Kaplan or Francis type turbine rotors cannot be used in proconsumer installations due to the complexity of design and high production costs of rotors for individual conditions. This also applies to the water inlet and drainage channels.

Due to frequent start-ups, typical solutions for hydrodynamic bearing arrangements of shafts with oscillating segments cannot be used, mainly due to the complexity of their structure, high costs and start-up difficulties [2.5].

Under the described conditions, much simpler Pelton type turbine rotors can be used, as well as a specially developed sliding system of radial-axial bearing with liquid lubrication, in which the start-up and overrun are supported by a properly made rolling bearing. In the proposed design solution, it is possible to use many recycled elements, mainly motor vehicles and work machines. It is also necessary to use systems enabling the storage of generated electricity for periods of forced shutdowns of proconsumer hydropower units.

Schematic diagram of a hydropower unit for individual use is shown in Fig. 1.

A simple impeller of the Pelton type 1 is mounted by means of expansion rings on the vertical main shaft 2, suspended on a special transverse-longitudinal bearing 3 with liquid lubrication; the shaft guiding is ensured by a radial bearing 4 with a self-lubricating sleeve. At the upper end of the shaft, two gears, e.g. with toothed belts 5, are mounted to increase the rotational speed of the main shaft. The gears 5 drive generators 6, that can be obtained e.g. from vehicles recycling. The electric current generated by the generators supplies the consumers (e.g. lighting) and charges the accumulator batteries 8 through a typical voltage regulator 7.

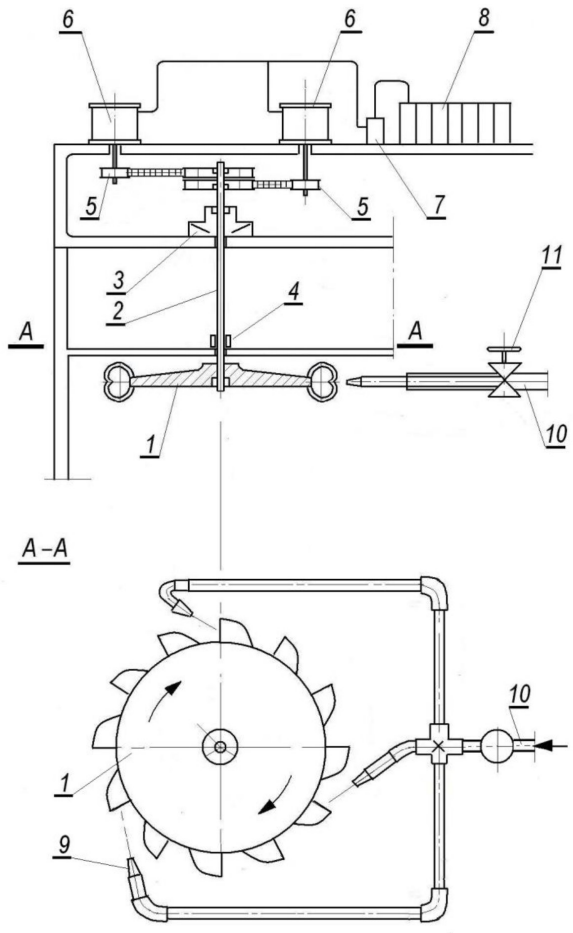

Fig. 1. Layout of the system of a proconsumer hydropower unit

The turbine rotor 1 is driven by water jets fed by evenly spaced nozzles 9 which are supplied from the central water pipeline 10 through the regulating valve 11. The nozzles 9 and the use of a double drive system of two generators cause that the main shaft is not exposed to significant transverse loads causing bending and transfers twisting moment, only. Suspending the shaft 2 on the bearing 3 as high as possible in a given localization situation eliminates the occurrence of compression longitudinal load in the shaft, which protects the shaft against buckling. The shaft can be made of a section of steel or duralumin pipe in normal manufacturing condition without the need for machining, if all rotating elements on the shaft are fixed with expansion rings (Fig. 2 – fixing the operating sleeve 3). The connections with the use of expanding rings can ensure efficient wedge-free connections, well transferring torque and longitudinal forces. They enable easy adjustment of the position of each of the joined elements along the shaft length, and facilitate the assembly of the gym system by the users themselves. Instead of a double drive system of generators, it is possible to use a toothed gear, e.g. planetary, with a coaxial input and output. The use of vehicle-type generators, in the event of the need to supply devices with mains voltage, requires the inclusion of a typical 12/24 V DC to 230 V AC mains voltage converter in the system.

Vehicle and machine accumulator batteries, which are used periodically by their nature, can be used as accumulators for storing the energy during the periods when the engine room is switched off. This applies, exemplary, to batteries for agricultural tractors and combine harvesters and others. These batteries left in vehicles and working machines require periodic recharging with electric current, especially in the period of the greatest energy deficit. Using them in the proposed energy storage plant will additionally increase their durability.

Wheels and gears with toothed belts used to drive generators may, like generators, come from recycling vehicles. This significantly facilitates the design of a proconsumer power unit and significantly reduces investment costs.

The water supply piping 10 from the upper reservoir can be made of conventional plumbing components.

The Pelton-type turbine rotor can be in the form of a disc on the circumference, which is mounted with evenly spaced blades in the form of dish-shaped elements pressed from sheet metal.

It is also possible to make the rotor disc, e.g. from tantalite with blades made of hard plastic and bolted connections to the disc, or in the form of a monolithic cast of Al-Mg alloy.

Axial and radial bearing of the main shaft in a small exposed water power plant for frequent start-up and shutdown periods

In the described proconsumer hydropower unit the particular role fulfils the special journal bearing with fluid lubrication. Additional roiling bearing, operating during the starts and slows down of the unit supports the start of this bearing; the design of this bearing presents Fig. 2.

The operating bush 3, by means of conical expansion rings 2, is mounted on the shaft 1 that is manufactured without offsets. The bush 3 is designed as the journal of the sliding axial radial bearing and it cooperates with the support 4 that is fully flooded in the lubricant 5 closed in the housing 6. On the supporting, non-movable bush 7 it is fixed the added rolling bearing 8; the coupling ring 9 rests on this bearing. In the rest state of bearing, the travelling bush 10 rests on the coupling ring 9 but travelling bush 10 is presses by the set of deflected arm 12 that are fixed on the axes 13 (cross-section A-A, Fig. 3).

During the start up of unit, the full load of bearing 6 transmits the supporting rolling bearing 8. At the increase in the rotational speed of the system and the increase in centrifugal force the movable arms 12 act on the loading elements 12 and they cause the gradual deflection of springs 15. It causes that the load applied to the sliding bush 10 decreases and the rolling bearing 8 is freed gradually form the load. Hence, the journal bearing is smoothly loaded because the fluid lubrication conditions just occurred.

Both types of bearings operate during the transitional period. Gradually, the sliding sleeve 10 is lifted up by the tensioned spring 11, the ends of which are engaged in the recesses of the operating sleeve 3 and the sliding sleeve 10. The rolling bearing then comes to a complete standstill, and the full thrust load Q and possible transverse load V is transmitted by the plain bearing under liquid lubrication conditions. The transverse load is transferred due to the conical shape of the sliding surface at the β angle. In addition, this ensures lateral stabilization of the shaft 1 and a favourable extension of the lubricant flow path between the sliding surfaces of the sleeve 3 and the support 4. The lubricant flows from the center towards the outside due to the centrifugal force associated with the rotation of the operating sleeve 3 carrying with it the heat generated in the journal bearing. After cooling, the lubricant returns to the input side of the bearing, as illustrated by the arrows in Fig. 2.

The circulation of the lubricant is favoured by oblique holes 4a and the gravitational change in density due to the heat transferred from the cooled bed 4.

The described method of operation of the entire system causes that the starting resistances are significantly reduced thanks to the rolling bearing and the slide bearing is protected against operational conditions of the lack of fluid friction. When the hydropower unit is shut down, the bearing system continues to run in reverse order, so that there is never any direct friction between the components in the journal bearing. The level of rotational speed at which automatic switching of the operation of both types of bearings takes place is controlled by the mass of the weights 12a and the preload of the springs 15 by turning the threaded plugs 16. The moment of switching the operation of the bearings can be observed through the transparent sight-glass 17 after illumination with a strobe lamp. In practice, it is sufficient to be guided by the clearly audible change in noise generated by the rolling bearing in relation to the practically silent operation of the journal bearing with liquid lubrication. Lubricant filler 20 integrated with the vent and the level indicator completes the entire bearing system.

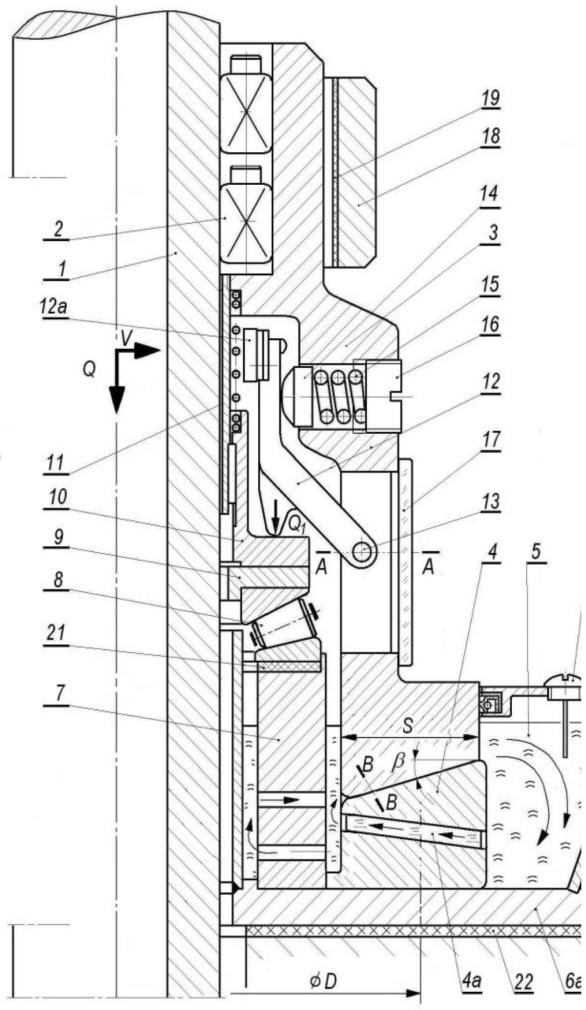

Fig. 2. Design of the axial-radial solution of main shaft of small hydropower unit

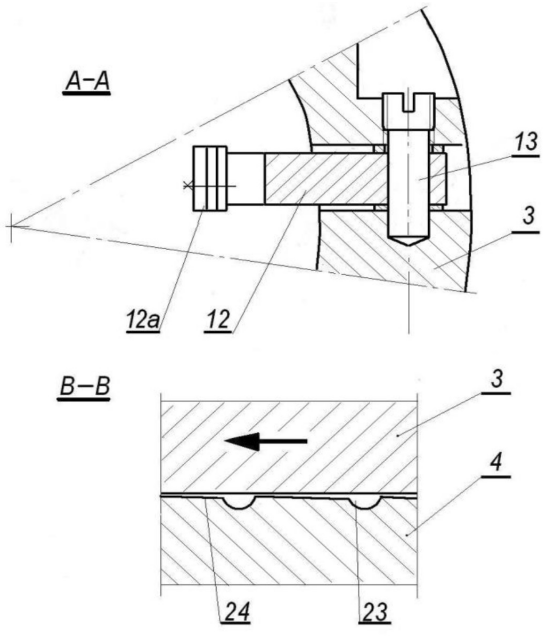

Fig. 3. Axial-radial bearing of the main shaft of small hydropower unit; (cross-section B-B, see Fig. 3)

If it is necessary to stop the bearing operation, a simple shoe brake 18 with a high-friction lining 19 can be used.

Vibration and noise reduction is ensured by polymer shims 21 and 22.

The bearing design allows for a larger bearing surface in the form of an increased width S and an average diameter D, which additionally increases the average speed of sliding in the journal bearing. Thanks to this, it is possible to use a lubricant of much lower viscosity for lubrication, the more so as it does not have to be selected due to the start-up [4]. This serves to reduce the resistance to the movement in the bearing and increasing the overall energy efficiency of the hydropower unit. Spiral grooves 23 and lubricating wedges 24 are made on the sliding surface, preferably a support, to increase the efficiency of lubricating film formation and cooling the friction zone (section B-B, Fig. 3).

The presented bearing of the main of shaft hydro power unit is characterized by a particularly high service life, as the supporting rolling bearing works for short periods of operation only at start-up and slow-down, while the journal bearing operates only under full hydrodynamic lubrication conditions, thus practically wear-free.

After the rotational speed control is performed, at which the operation of both types of bearings is switched, and the position of the water nozzles is determined, the current operation of the hydro power unit is limited to opening/closing the main water supply valve 11 from the upper reservoir of the power plant.

Summing up

The described concept of a proconsumer small hydropower unit is characterized by simple design and reduced investment costs thanks to the use of largely recycled components.

The design of a small hydropower unit can be implemented with a large participation of direct users of the generated electricity. The system enables to achieve high technical and economic effects in the form of network energy savings. It is especially designed for the applications where the availability of energy is limited. Hybrid bearing of the main shaft of the unit ensures easy start-up and high-energy efficiency with a particularly long service life.

References

[1] Lubośna Z., Wind farms in the power system. WNT. W-wa. 2006. in Polish)

[2] Wasilczuk M., Large-size Hydrodynamic Thrust Bearings. Scientific Publisher ITE. 2012. Radom.(in Polish)

[3] Dąbrowski Z., Neyman A., Wasilczuk M., Axial Bearings - Contemporary operational problems. Machine Operation. Issues. Book 3 (139). 2004. in Polish)

[4] Lawrowski Z., Plain bearings. Ed. Wrocław University of Science and Technology. 2001. Wrocław. (in Polish).

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ANTIOXIDATIVE PROPERTIES OF AUTUMN OLIVE (*ELAEAGNUS UMBELLATA*) FRUITS ACCORDING TO THE METHOD OF FRUIT PRESERVATION AND SOLVENT USED IN EXTRACTION

WŁAŚCIWOŚCI ANTYOKSYDACYJNE OWOCÓW OLIWNIKA BALDASZKOWATEGO (*ELAEAGNUS UMBELLATA*) W ZALEŻNOŚCI OD SPOSOBU UTRWALANIA OWOCÓW I ROZPUSZCZALNIKA UŻYTEGO DO EKSTRAKCJI

Summary: *Fruits of autumn olive (Elaeagnus umbellata) are the abundant source of antioxidative substances such as carotenoids, polyphenols, flavonoids, fat-soluble vitamins and Vitamin C. The conducted study was aimed at the selection of the optimum method for extraction of berries. To this end, two methods for preservation of the berries were compared: drying at 60°C and freeze-drying (lyophilisation) and two types of solvent, employed in the extraction: water and methanol. The results showed that the methanol extracts produced from lyophilized fruits were characterized by the highest antioxidative activity*

Keywords: *Autumn olive, plant extracts, antioxidative activity, antioxidant, functional food*

Streszczenie: *Owoce oliwnika baldaszkowatego (łac. Elaeagnus umbellata, ang. Autumn olive) są bogatym źródłem substancji antyoksydacyjnych, takich jak karotenoidy, polifenole, flawonoidy, witaminy rozpuszczalne w tłuszczach oraz witamina C. Przeprowadzone badanie miało na celu wybranie optymalnej metody ekstrakcji jagód. W tym celu porównano dwie metody utrwalania owoców: suszenie w 60°C i liofilizację oraz dwa rodzaje rozpuszczalników użytych do ekstrakcji: wodę i metanol. Wyniki wykazały, że najwyższą aktywnością antyoksydacyjną charakteryzowały się ekstrakty metanolowe wykonane z owoców liofilizowanych.*

Słowa kluczowe: *oliwnik baldaszkowaty, ekstrakty roślinne, właściwości antyoksydacyjne, antyoksydanty, żywność funkcjonalna*

Introduction

Genus *Elaeagnus* includes numerous species of bushes which produce fruits having the nutritive and decorative values. In Asia countries, the mentioned berries are employed in the traditional medicine and, also, serve as food. In Europe, they are mainly known as decorative plants. The discussed bushes are eagerly planted as hedge due to their easy adaptation to environmental conditions, compact structure, resistance to the high and low temperature and soil salinity [1].

During the recent years, there have appeared many reports confirming the health-promoting properties of the fruits and leaves of autumn olive which were earlier in the traditional medicine [2–8]. Due to the mentioned reason, the interest in autumn olive as a raw material for production of functional food and diet supplements has increased also in Europe. Such utilization requires, in most cases, preservation of berries, and removal of water in particular as its content contributes to quicker deterioration of the product. Besides it, it is necessary to concentrate the bioactive substances by their extraction from the initial material. As it is known, the method of the raw material preparation (especially the temperature of treatment) and the reagent used in the extraction have a significant effect on the content of bioactive compounds in the extract [9].

The choice of the appropriate methodology of preserving and extracting the plant raw material in connected, first of all, with the chemical properties of its biologically active compounds. Berries of autumn olive contain numerous antioxidants, differing in the sensitivity to temperature and in solubility. Dark-red colour of the berries is caused by the content of the high quality carotenoids, from which relatively-resistant-to-processing likopen is dominating [10–12]. Pro-vitamin A and vitamin E are other fat-soluble compounds which are more sensitive to temperature effect. *E. umbellata* berries are also abundant in water-soluble vitamin C [1, 13]. Its effect, consisting in elimination of free radicals, is very quick but the discussed vitamin is

extremely sensitive to temperature and effect of sunlight; when administrated in high doses, it reveals a pro-oxidative effect [14]. Phenol compounds, and, in particular, polyphenols are an interesting group, responsible for a considerable part of antioxidative effect of plant raw materials. Free phenol acids reveal the hydrophilic properties, free flavonoids – lipophilic ones, and their derivates (esters and glycosides) are partially hydro- and lipophilic. Due to their presence in water as well as in fat phase, they are considered as the most comprehensive antioxidants [15].

The treatment of plant raw materials at a high temperature is related to a lower antioxidative capacity. The mentioned effect is a result of degradation of bioactive compounds, as affected by a high temperature and also, by the activation of oxidative processes. To preserve the antioxidative properties by the raw materials, the process of lyophilisation is recommended; it consists in sublimation of water from the samples with the application of a low temperature and vacuum [9, 16]. It is not, however, deprived of defects. One of them includes the necessity of initial freezing of the raw materials, higher interference into the cellular structure [9] and, also, high costs in relation to drying process.

It might seem that the lowest possible temperature should be employed but the results of the studies are not univocal. The analysis of blueberry fruit revealed that the samples subjected to lyophilisation process were characterized by lower antioxidative properties (after consideration of the process yield) as compared to the fresh, frozen, pasteurized berries as well as jams made from fresh berries [17]. Sometimes, drying at a high temperature but for a shorter period of time allows maintaining the higher amount of antioxidants. The studies carried out on the carrot root showed that the content of carotenoids had the highest value in the samples dried at the lowest temperature (40°C) even for a longer time. However, in the same study, the loss of the heat-labile vitamin C was lower in the case of higher temperature (60°C) but during the shorter drying period [18]. From among carotenoids, likopen deserves a special attention; it is one of the stronger plant antioxidants and the main dye of ripen berries of autumn olive [12]. Numerous studies indicate that processing with the application of high temperature did not have the unfavourable impact on its content in the product. Besides it, the treatment processes such as cooking, steaming or microwave heating affected the change of likopen structure into more assimilable by humans and monogastric animals [11, 19].

The choice of the appropriate temperature of berries' processing is also not univocal in the case of polyphenols, being considered as the main compounds, responsible for antioxidative properties of many plant species. The studies of the grape marc showed that it was possible to preserve even 90% of phenol compounds during the extraction at temperature up to 150°C if the heating did not last longer than 1 minute. Semi-liquid marc was more sensitive as compared to the filtrated liquid extract [20]. Such short time of heat treatment is, however, insufficient for preservation of the product.

The next challenge, which may have an impact on the antioxidative properties of the extract, is the appropriate choice of solvent. In the case of autumn olive, ethanol or methanol alcohol is the extractor being most frequently described in literature [2, 5, 6, 8]. However, polyphenols are, in majority, well soluble in water; owing to this fact, they act well in water systems such as biological fluids. Ishaq et al, showed that water extracts of autumn olive berries had the highest level of phenol compounds and of flavonoids and revealed the strongest effect, preventing from oxidation in brain and liver of mice as compared to methanol, acetone and hexane extracts [21]. The mentioned extraction is also safer for analyst and for the environment.

The aim of the present study was to develop the optimum method for handling with the autumn olive berries in aspect of obtaining the extracts with strong antioxidative properties. To this end, the extracts obtained from lyophilised (free-dried) berries and those ones dried and extracted with water of methanol, were compared.

Materials and methods

The autumn olive berries were collected after obtaining the stage of ripeness in the farm, situated at the territory of the Łódzkie voivodeship. A part of material was lyophilised and another part was dried in the traditional dryer at 60°C. The both mentioned processes were carried out in two repetitions. To calculate the yield of the process, the sampled were weighed before and after the treatment in analytical balance with accuracy of 0.01 mg (Radwag).

Then, for each type of raw material, extraction with deionised water or 96-% methanol of analytical grade was carried out. The sample was poured with solvent in ratio (1:20), shaken for one hour and subjected to ultrasounds (100W) for 5 minutes. Next, the upper layer was filtrated on the Whatman filter (18.5 cm). Four types of extracts were obtained.

Alcohol extracts were evaporated at 50°C in vacuum evaporator (Büchi R-210) and water extracts were lyophilised (Lyovac GT 2). The resulting powders were stored in dark until the time of analyses. The parameters were selected on the grounds of the procedures obligatory in the laboratory.

To calculate the yield of the process, the raw materials and the resulting extracts were weighed in two repetitions in analytical balance with accuracy of 0.01 g (Radwag).

DPPH Assay

The ability to inhibit the oxygen, radical DPPH (DPPH, eng. 2,2-diphenyl-1-picryl hydrazyl radical) was measured in the same way as in the earlier work of the team [8, 10]. 280 µl of 0.1 mM solution DPPH was combined with the extracts of concentration equal to 3 mg/ml. For each type of extract, six repetitions were performed. After 20-min incubation in dark, the absorbance at 517 nm wave in plate spectrophotometer Nano-200 (Tecan, Switzerland) was read out. The results were submitted as the percentage of neutralized radicals and were calculated from the following formula:

% of inhibition DPPH = (A0 – A1) /A0 x 100

where:
A0 - is the initial value of absorbance of radical DPPH
A1 – is the absorbance of radical after reaction with the sample

FRAP Assay (eng. Ferric reducing antioxidant power)

Capacity to reduce ferric ions Fe (III) to Fe (II) was tested according to Matusiewicz et al. [22]. Extracts were mixed in ratio 1:1 with 0.2 M sodium-potassium buffer (PBS) having pH 6.6 and 1-% potassium ferricyanide. After incubation in water bath (50°C, 20 min), 10% TCA was added to the samples. After centrifugation, they were diluted twice in deionised water. Next, 0.1% ferric chloride was added and the absorbance at 700 nm wave was measured (Infiniti NANO 200, Tecan, Switzerland). For each type of extract, six repetitions were performed. The results were presented as TROLOX equivalent (synthetic analogue of vitamin E) on the grounds of the standard curve, developed in the range 0-80μM.

Laboratory is functioning in accordance with standard ISO/IEC 17025 "General requirements for the competence of testing and calibration laboratories".

Results and discussion

Yield of drying and lyophilisation processes has been given in Tab.1.

Tab.1. Weight loss of E. umbellata berries after drying at 60°C and lyophilisation. N=2°

Method of berries' preservation	Mean weight loss (%)	Time (hours)
Drying at 60°C	80.02	4
Lyophilisation	78.89	24

Drying at 60°C and lyophilisation were characterized by a similar weight loss, with a small domination of the first mentioned process. When taking into consideration the time which in the case of lyophilisation was twelve times longer, it may be stated that drying seems to be more optimum method for preservation of autumn olive berries.

The yield of extraction process (Tab. 2) was higher when methanol was employed as solvent, in comparison to water as it was earlier evaluated by the team from Turkey [21]. The yield recorded in the present study was considerably higher as in the case of earlier assays what probably results from the application of more intensive shaking and ultrasounds. Again, the lyophilised berries had a higher yield of extraction than their dried equivalents (Tab. 2). More intensive interference into the cellular structure during lyophilisation was already earlier related to higher sensitivity of the processed raw material to the contact with solvent [9].

Tab.2. Yield of extraction of E. umbellata berries, with the consideration of the method for preservation of the raw material and of the employed solvent. N=2

Type of extraction	Yield (%)
Alcohol extract from dried berries	33.49%
Alcohol extract from lyophilised berries	37.31%
Water extract from dried berries	27.81%
Water extract from lyophilised berries	29.95%

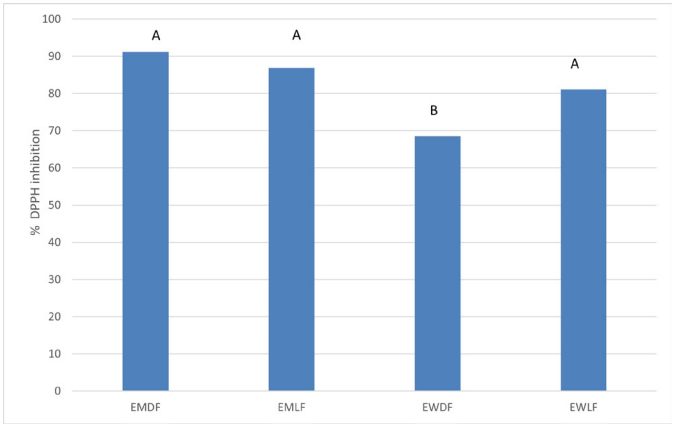

Fig.1. Ability to inhibit radical DPPH by autumn olive berries subjected to different extraction processes: EMLF – methanol extracts from lyophilised berries; EMDF – methanol extracts from dried berries; EWDF – water extracts from dried berries; EWLF – water extract from lyophilised berries. N=6. Different letters mean that the groups differ statistically at p<0.05

All obtained extracts revealed antioxidative properties. The lowest ability of inhibiting the synthetic oxygen radical DPPH was recorded for the water extracts from dried berries (Fig. 1). Any statistically significant differences between the remaining groups were not found although there was a visible tendency to stronger effect of alcohol extracts. It is supported by the results obtained for the berries coming from Pakistan. Khattak revealed that the extracts from autumn olive, produced with the participation of methyl alcohol and dried at 45°C, had stronger antioxidative effect as compared to the acetone and water extracts [13]. Another team of scientists showed that extracts with the application of methyl alcohol had the lowest value of EC50 (the concentration which is able to inhibit a half of radicals DPPH) in comparison to acetone, hexane and ethyl acetate [23].

Assay of the ability to inhibit radical DPPH is the most frequently used test for evaluation of antioxidative properties. It is, however, not deprived of certain defects. The basic problem is the presence of ions of transitory metals in the fruit extracts (especially of iron and cooper) which participate actively in generation of free radicals (reactions of Fenton and Haber-Weiss). It was found that the presence of ions of many metals (inter alia, ferric, cooper, calcium and potassium ions) had a negative effect on the run of DPPH reaction with antioxidants [24]. Therefore, it is recommended to apply the additional confirming methods when testing the natural products.

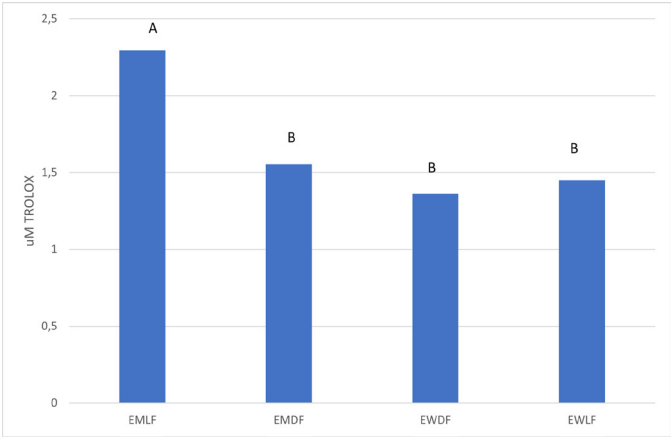

Fig.2. Ability to reduce ferric ions by autumn olive berries subjected to different extraction processes: EMLF – methanol extracts from lyophilised berries; EMDF – methanol extracts from dried berries; EWDF – water extracts from dried berries; EWLF – water extract from lyophilised berries. N=6. Different letters mean that the groups differ statistically at p<0.05

More information may be obtained from the test, examining the ability of antioxidants to reduce ferric ions Fe (III) to Fe (II). Alcohol extract from lyophilised berries was characterized by the highest donor activity. The statistical analysis showed that the application of alcohol as a solvent increased significantly the force of recuing ferric ions in relation to water extraction, irrespectively of the method of dehydration of the raw material ($p<0.05$). Similarly, the lyophilised berries were characterized by stronger antioxidant activity as compared to dried fruits, irrespectively of the employed reagent.

Also, Ozen et al. [3] showed stronger activity of alcohol extracts in comparison to water extracts in FRAP test and total antioxidant status (TAS) in the case of dried berries of autumn olive. Contrary to it, in the assay, testing the reduction capacities (DPPH), the team from Turkey demonstrated higher antioxidative properties of water extracts. Ishaq et al. revealed that in spite of a lack of differences in ferric iones' reduction between the alcohol and water extracts, the water extracts had stronger antioxidative effect in brain and liver of mice [21].

According to the knowledge of the authors, the comparative studies concerning the antioxidant properties of the dried and lyophilised *E. umbellata* berries have not been carried out until now. Similarly as in the present study, the lyophilised berries protected more strongly from the oxidative processes in comparison to the dried fruits in the case of wild rose (*Rosa rugosa*), strawberry tree (*Arbutus unedo*), [26], raspberry (*Rubus ideaus L.*), strawberry (*Fragaria ananassa*) and blueberry (*Vaccinum myrtillus*) [27].

The discrepancies between the results of different methods, testing the antioxidant properties are frequent. To understand them, we should consider the assumptions of the tests. The basic defect of FRAP method results from the fact that the ability to reduce complex Fe (III) with (2,4,6-tris(2-pirydylo)-1,3,5-triazyne (TPTZ) is revealed also by other compounds which are not classified as antioxidants. So, it may give the too high results. On the other hand, not all antioxidative compounds show the capability to reduce ferric ions. The endogenous protein antioxidants such as, inter alia, glutathione, act as strong antioxidants, however their activity will be not considered in FRAP method. Autumn olive berries contain relatively low (ca.5%) level of total protein in dry solids [13]. Adulteration will be higher in the case of high-protein products.

The comparison of the studies, examining the extracts, is also hampered due to the possible differences in running the extraction process and earlier preparation of the extract. It is known that even subtle changes in production of extracts (including, inter alia, degree of the raw material disintegration, temperature and application of ultrasounds) [28] may affect their properties. Moreover, each team prepares the extracts according to own method and the protocols are often insufficiently precise as to reproduce such process in the ideal way.

Podsumowanie

The conducted study showed that in order to obtain extracts from autumn olive berries with antioxidative properties, the choice of methyl alcohol as extractor was more favourable than in the case of water. FRAP assay (reduction of ferric ions) indicates also that the extracts obtained from lyophilised berries have a greater antioxidative effect as compared to the fruits dried at 60°C. The further research work is necessary which would show the effect of different drying temperatures on the antioxidative properties of *E. umbellata*.

Bibliography

[1] Gamba G, Donno D, Mellano MG, Riondato I, Biaggi M De, Randriamampionona D, et al. Phytochemical Characterization and Bioactivity Evaluation of Autumn Olive (Elaeagnus umbellata Thunb.) Pseudodrupes as Potential Sources of Health-Promoting Compounds. Appl Sci 2020, Vol 10, Page 4354. 2020;10(12):4354.

[2] Lee J, Sung JM, Cho HJ, Woo SH, Kang MC, Yong HI. Natural Extracts as Inhibitors of Microorganisms and Lipid Oxidationin Emulsion Sausage during Storage. Food Sci Anim Resour. 2021;41(6):1060.

[3] Ozen T, Yenigun S, Altun M, Demirtas I. Phytochemical Constituents, ChEs and Urease Inhibitions, Antiproliferative and Antioxidant Properties of Elaeagnus umbellata Thunb. Comb Chem High Throughput Screen. 2017;20(6).

[4] Qayyum R, Qamar HMUD, Salma U, Khan S, Khan T, Shah AJ. Insight into the cardiovascular activities of elaeagnus umbellata. Farmacia. 2019;67(1):133–9.

[5] Kim JI, Baek HJ, Han DW, Yun JA. Autumn olive (Elaeagnus umbellata Thunb.) berry reduces fasting and postprandial glucose levels in mice. Nutr Res Pract. 2019;13(1):11–6.

[6] Nazir N, Zahoor M, Nisar M, Karim N, Latif A, Ahmad S, et al. Evaluation of neuroprotective and antiamnesic effects of elaeagnus umbellate thunb. On scopolamine-induced memory impairment in mice. BMC Complement Med Ther. 2020;20(1):1–17.

[7] Gamba G, Donno D, Mellano MG, Riondato I, De Biaggi M, Randriamampionona D, et al. Phytochemical Characterization and Bioactivity Evaluation of Autumn Olive (Elaeagnus umbellata Thunb.) Pseudodrupes as Potential Sources of Health-Promoting Compounds. Appl Sci 2020, Vol 10, Page 4354 [Internet]. 2020 Jun 25 [cited 2022 Mar 23];10(12):4354.

[8] Zglińska K, Niemiec T, Łozicki A, Matusiewicz M, Szczepaniak J, Puppel K, et al. Effect of Elaeagnus umbellata (Thunb.) fruit extract on H_2O_2-

-induced oxidative and inflammatory responses in normal fibroblast cells. PeerJ. 2021.
[9] Kamiloglu S, Toydemir G, Boyacioglu D, Beekwilder J, Hall RD, Capanoglu E. A Review on the Effect of Drying on Antioxidant Potential of Fruits and Vegetables. Crit Rev Food Sci Nutr. 2016 Jul 29 [cited 2022 Mar 21];56 Suppl 1:S110–29.
[10] Zglińska K, Rygało-Galewska A, Bryś J, Koczoń P, Borek K, Roguski M, et al. Elaeagnus umbellata fruit - chemical composition, bioactive compounds, and kinetic of DPPH inhibition compared to standard antioxidants. Emirates J Food Agric. 2021. 1;33(8):639–46.
[11] Skiepko N, Chwastowska-Siwiecka I, Kondratowicz J. Właściwości likopenu i jego wykorzystanie do produkcji żywności funkcjonalnej. Żywność Nauk Technol Jakość. 2015;22(6):20–32.
[12] Fordham IM, Clevidence BA, Wiley ER, Zimmerman RH. Fruit of Autumn Olive: A Rich Source of Lycopene. HortScience. 2001;36(6):1136–7.
[13] Khattak KF. Free radical scavenging activity, phytochemical composition and nutrient analysis of Elaeagnus umbellata berry. J Med Plants Res [Internet]. 201;6(39):5196–203.
[14] Niemiec T, Sawosz E, Chwalibog A. Effect of high doses of L-ascorbic acid on theantioxidative/oxidative state in the rats. J Anim Feed Sci. 2005 Jun 26;14(Suppl. 1):553–6.
[15] Materska M. Wpływ warunków ekstrakcji na zawartość 0-glikozydów kwercetyny w preparatach z owoców papryki [Internet]. Żywność: nauka - technologia - jakość. 6. 91. 2013:131–50.
[16] Shofian NM, Hamid AA, Osman A, Saari N, Anwar F, Dek MSP, et al. Effect of Freeze-Drying on the Antioxidant Compounds and Antioxidant Activity of Selected Tropical Fruits. Int J Mol Sci 2011, Vol 12, Pages 4678-4692. 2011;12(7):4678–92.
[17] Kluszczynska D, Sowinska W. Wpływ procesów technologicznych na zawartość substancji bioaktywnych w owocach borówki czernicy. Żywność Nauk Technol Jakość. 2014 May 2;21(4):30–42.
[18] Mohamed S, Hussein R. Effect of low temperature blanching, cysteine--hci, N-acetyl-L-cysteine, Na metabisulphite and drying temperatures on the firmness and nutrient content of dried carrots. J Food Process Preserv. 1994:18(4):343–8.
[19] Gryszczyńska A, Gryszczyńska B, Opala B. Postępy Fitoterapii 2/2011.
[20] Sólyom K, Solá R, Cocero MJ, Mato RB. Thermal degradation of grape marc polyphenols. Food Chem. 2014 Sep 15;159:361–6.
[21] Ishaq S, Habib A, Rathore SM. Antioxidant Properties of Elaeagnus umbellata Berry Solvent Extracts against Lipid Peroxidation in Mice Brain and Liver Tissues. Food Sci Biotechnol. 2015;24(2):1–7.
[22] Matusiewicz M, Bączek KB, Kosieradzka I, Niemiec T, Grodzik M, Szczepaniak J, et al. Effect of Juice and Extracts from Saposhnikovia divaricata Root on the Colon Cancer Cells Caco-2. Int J Mol Sci 2019, Vol 20, Page 4526
[23] Uddin G, Rauf A. Phytochemical screening and biological activity of the aerial parts of Elaeagnus umbellata. Sci Res Essays. 2012;7(43):3690–4.
[24] Dawidowicz AL, Olszowy M. Mechanism change in estimating of antioxidant activity of phenolic compounds. Talanta [Internet]. 2012;97:312–7.
[25] Rutkowska J, Adamska A, Pielat M, Białek M. Porównanie składu i właściwości owoców dzikiej róży (Rosa rugosa) utrwalanych metodami liofilizacji i suszenia konwencjonalnego - Żywność Nauka Technologia Jakość. 2012. Tom 19, Numer 4.
[26] Orak HH, Aktas T, Yagar H, Isbilir SS, Ekinci N, Sahin FH. Effects of hot air and freeze drying methods on antioxidant activity, colour and some nutritional characteristics of strawberry tree (Arbutus unedo L) fruit. Food Sci Technol Int. 2012;18(4):391–402.
[27] Michalczyk M, MacUra R, Matuszak I. The Effect Of Air-Drying, Freeze--Drying And Storage On The Quality And Antioxidant Activity Of Some Selected Berries. J Food Process Preserv. 2009. 1;33(1):11–21.
[28] Wyrostek J, Kowalski R. Wpływ ultradźwięków i rozdrobnienia surowca na ekstrakcję związków fenolowych i flawonoidów z liści mięty pieprzowej i herbaty czarnej. Przem Chem. 2022; T. 101, nr 2.

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INTERNATIONAL DAY OF ENGINEERING OF SUSTAINABLE DEVELOPMENT

interview with Ewa Mańkiewicz-Cudny, president of FSNT-NOT

ŚWIATOWY DZIEŃ INŻYNIERII ZRÓWNOWAŻONEGO ROZWOJU

wywiad z Ewą Mańkiewicz-Cudny, prezes FSNT-NOT

Engineering has, for centuries, played a key role in civilization development of our Globe and, also in solving of the most important local and global problems, including, *inter alia*, ecological safety. It decides on technological, social and economic progress in all domains, with the consideration of the principles of sustainable development. The contemporary world necessitates more and more modern engineering knowledge in order to minimize the consequences of devastation of natural environment and climatic changes, reduction of contamination, introduction of zero-emission industrial production and improvement of living standard and health level of inhabitants.

***– The celebration of the International Day of Sustainable Development Engineering is the occasion for debate on the mentioned subject in the environment of scientists and practitioners* – Ewa Mańkiewicz-Cudny, the President of FSNT-NOT says.**

Jolanta Czudak: *The achievements of the engineering creators have been known for centuries; why as late as now are we celebrating the International Day of the Sustainable Development?*

Ewa Mańkiewicz-Cudny: Engineering is undoubtedly one of the basic domains, deciding on civilization progress of the world, with the consideration of the principles of sustainable development. Such practices have been appreciated for a long time in various branches of industrial and constructional production, energetic systems, transport, waste management, or environment restoration. Each sector that utilizes resources and natural raw materials should employ such measures. The role of engineers in the discussed activity was always a leading one but until the recent time, they had not their holiday. Such resolution was adopted as late as during the International Congress of Engineering in 2019, in Melbourne, being organized by the World Federation of Engineering Organizations (WFEO) and UNESCO.

Who was the initiator of introducing the International Day of Sustainable Development Engineering?

WFEO and UNESCO in common suggested proclaiming 4 March as the International Day of Sustainable Development Engineering during the debates of the mentioned above Congress, participated by ca. 3 thousand delegates from more than 100 countries. In the speeches of the participants, it was stressed that the question of sustainable development was most frequently discussed by economists and lawyers in the context of legal regulations or financial operations. The most important aspect, concerning the indication of the direction for civilization development which is dependent on the scientific-technological progress, was omitted. That's exactly that the scientists, engineers and technology creators have a deciding voice in the implementation of ideas of the sustainable development. The participants of the discussed Congress recognized that the world listened them not enough, and focused the attention mainly on the economic consequences; therefore, the introduction of the International Day of Sustainable Development Engineering will become the occasion for appreciation of the role of engineering creators and their achievements. It will allow a more comprehensive discussion on the challenges standing before the engineers, with the consideration of the principles of combining the development and ecological conditions, and with the indication of the role of engineering activity in the life of the societies and single personss.

What are the most important challenges for the engineering environment in respect of implementation of the sustainable development idea?

The increasing climatic changes generate many problems, requiring their solution by the engineers. Reduction of greenhouse gas (GHG) emission, development of new technologies in respect of reasonable water management (treatment and saving), unquestionable savings of energy, natural resources and raw materials, minimization of the consequences of natural disasters, development of circular economy system are only certain examples of the mentioned activity. The list is long and

includes introduction of technological changes not only in the industrial, urbanistic, transport or economic activities but also in biotechnology, telemedicine and many other domains. The change in social awareness in respect of utilizing our Planet resources is also meaningful. Practical utilization of engineering achievements improves living standard, facilitates a wide access to culture property, modern diagnostic and treatment methods. Pandemic COVIV-19 showed the meaning of engineering creators, not only in creation of technologically advanced equipment for human life saving but also in development of informatics tools which ensured the possibility of remote communication of the society and the possibility of conducting education and vocational work. Engineering plays a deciding role in the implementation of the assumptions of sustainable and civilization development. The common holiday of the engineering environment creates the possibility of discussion on the mentioned achievements and challenges and, what is also important, of showing them to the society.

Are the engineers eager to join in the celebration of their holiday?
We organized it only twice and, moreover, in rather unfavourable situation due to pandemic but the members of Polish delegation in Melbourne accepted enthusiastically information on the establishment of the International Day of Sustainable Development Engineering. Polish delegation during the Congress in Melbourne was quite numerous. It was 23-person representation of scientific, engineering and industrial environment. We all decided to join actively in the celebration of the discussed holiday which has to emphasize the role of engineering creators and the meaning of their work for the society and economy. In 2020, Poznań University of Technology was the partner of FSNT-NIT. The first celebration of the discussed holiday was held in Poznań under the motto of "Sustainable development". It was dedicated to the perspectives for artificial intelligence and resembling the contribution of Polish engineers to development to the world civilization. In 2021, the ceremony was organized under the motto "Healthy Planet" and was organized together with Silesian University of Technology but in "on-line" formula.

What will be the motto of this year's celebration of the International Day of Sustainable Development Engineering?
This year, the celebration of March, 4 is carried out under the motto "Let's reconstruct better engineering for the future"; our partner is Warsaw University of Technology. Better engineering is understood as such technology which serves people well, improves living standard, ensures safety and eliminates hazards. We live, unfortunately, in the world of increasing military, climatic, ecological, health, existence and cybernetic threats and many other dangers. It is dependent on the engineering creators how we will cope with the mentioned problems. It the civilization is to survive, it is the last moment for reconstruction of better technology. It is our main subject; apart from it, we want to talk about the contribution of engineers to the development of science, medicine, technology and economy. The inaugurating speech of Prof. Mariusz Malinowski, the Vice-Rector of Warsaw University of Technology for scientific matters will be dedicated to new technologies in energetics as the answer to the challenges of the European Green Deal. From among many important issues, there will be found the problems connected with the utilization of the crucial medicinal solutions in diagnostics and treatment of patients, including, inter alia, the persons with hearing defects. Prof. Henryk Skarżyński will share with his knowledge and achievements. He is not only the outstanding physician but also the creator and inventor of implants and modern hearing equipment which serve the patients all over the world to come back to the world of sounds. He created the transnational centre in Falenty where the treatment of the patients as well as education of specialists is carried out. We want to show that everything is possible owing to engineering. We will also focus on digitalization, internet of things, industry 4.0, and standardization which optimizes all process, and on perspectives for education of engineers for the future. During our conference, the appearance of the representatives of Student Circles of Warsaw University of Technology is provided. They will tell us about their achievements as young creators. The celebration of the International Day of Sustainable Development Engineering will be commenced at 10.30 a.m. The conference will be held in the on-line system. It is possible owing to NOT Informatics company, functioning in the structures of the Federation of Science and Engineering Associations (FSNT)-NOT. The mentioned company created a perfect informatics system and various applications aiming at the support of our statute activity and of the associations acting in the Federation. We have a safe communicator for the remote organization of events and secret voting system. Owing to the mentioned instruments, we may successfully implement the on-line meetings. This year's celebration will be also prepared in the mentioned formula.

We invite to the participation in the discussed event, after the filling the previous formalities connected with the registration at the page of FSNT-NOT (sdi.enot.pl)

It was the interview with Ewa Mańkiewicz-Cudny, the President of the Board of FSNT-NOT, carried out by Jolanta Czudak (03.03.2022)

Better engineering is meant as such technology which serves the people well, improves living standard, ensures safety and eliminates hazards.

Dodatkowe informacje na stronie www.sigma-not.pl
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