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Characteristics of Indigestible Foreign Materials in Forestomach of Dairy Cows in Different Farm Types

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Abstract

The aim of the study was to assess the relevance of plastic ingestion in dairy cows depending on the management practice and the size of the farm. The research was conducted during 2015–2020 in the central part of Ukraine. The presence of foreign bodies in the rumen was detected during diagnostic rumenotomy or postmortem in backyard (1–8 animals), small traditional (usually 50–200 animals) or modern large farms (500–1000 dairy cows). The study showed that plastic materials and their derivates are the main component of indigestible foreign bodies found in cows' forestomach. Big pieces of plastic and conglomerates with plastic material cause prolonged chronic forestomach dystonia in dairy cows in 93%, 91%, and 82% of cases on backyard, traditional, and modern dairy farms, respectively. Nylon ropes, bale nets, plastic bags, packaging material, pieces of clothing, and rags were most frequently found in cows from backyard farms. Metal items, nylon ropes and nets, polyethylene fodder films, and plastic medicine packaging were the most frequent items found in cows from traditional and modern farms. Proper plastic waste management on the farms has to be an integral part of preventing forestomach diseases, decreasing culling rate, and increasing level of welfare in dairy cows.

Keywords: Cow, plastic pollution

Introduction

Numerous scientific studies demonstrate widespread contamination of the environment with plastic debris (Basto et al., 2019; Collard et al., 2019; Mucientes & Queiroz, 2019; Rochman et al., 2016). Massive production of plastic material started in the 1950s and since then its share in the world's pollution has reached 10% and still continues to grow (Barnes et al., 2009). According to Rhodes (2018), in the recent 4 years as much plastic was produced in the world as during the previous half century. The author also claims that the total mass of virgin plastic ever made in the world amounts to 8.3 billion tons. Only between 1950 and 2015, 6.3 billion tons of primary and recycled plastic materials were generated, of which around 9% was recycled, and 12% destroyed by burning, with the remaining 79% either being stored in garbage dumps or having been spread into the natural environment.

The distribution of plastic debris is mainly related to poor waste management (Battulga et al., 2019). Plastic debris pose considerable danger for wildlife and domestic animals (ingestion, internal impaction, choking and starving), and may facilitate the distribution of non-native and potentially harmful microorganisms and a toxic substances (Barnes et al., 2009).

At the same time, we know little on the current magnitude of plastic danger (O'Hanlon et al., 2017). Li et al. (2016) summarized the potential hazards of the plastic uptake by living organisms, and concluded that plastic substances can be potentially incorporated into the food chain. Thus, one of the most important

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negative consequences of the plastic pollution is the ingestion of plastic debris by wildlife and domestic animals (Baak et al., 2020; Fernández & Anastasopoulou, 2019; Rizzi et al., 2019; Seif et al., 2018; Zhu et al., 2019).

Thus, swallowing of indigestible foreign materials (IFMs) in domesticated species is of substantial economic and health importance (Mushonga et al., 2015). For this reason, plastic ingestion research is of crucial importance to evaluate the ongoing and regional changes and to be able to develop proper monitoring and management strategies (Avery-Gomm et al., 2018; Nicastro et al., 2018).

Mahadappa et al. (2020) found a significant decrease in the rumen protozoal density and motility, increase in the rumen fluid pH, methylene blue reduction time, and sedimentation activity time in animals that ingested plastic. The concentration of heavy metals in the body fluids and tissues was also significantly higher in animals affected with rumen impaction by plastic debris.

Researching the problem of rumen plastic impaction, Priyanka and Dey (2018) suggest that ingested plastic materials slowly release the chemicals into the rumen fluid, which brings the danger of introduction of the chemicals to the food chain through accumulation in milk and meat products. The authors consider possible detrimental effect these chemicals may have on human.

Otsyina et al. (2017) evaluated the gross and histopathological changes caused by plastic impaction of the rumen in sheep. The gross changes associated with plastic rumen impaction consisted of atrophy of the body muscle and fat, atrophy, and fibrosis of the internal organs (spleen, liver, and kidneys). Gross lesions in the rumen were detected as atrophy, thinning and loss of rumen papillae, erosion, ulcerations, and nodular formations on the rumen mucosa. The prominent histopathological changes included parakeratosis, edema, and severe multiple degeneration of the mucosal layer. The authors suggest that observed pathological changes may contribute to clinical signs, poor condition, and productivity by hindering the absorption of nutrients.

Dong et al. (2020) noted that chlorinated paraffin is often used in plastic manufacturing, and the plastic with chlorinated paraffin is widely used for storage of animal feed. The authors found that migration of paraffin to feedstuff increases with increased storage time and temperature. Dorne et al. (2013) emphasized the possible melamine contamination because of its use as a feed contact material in plastic and laminate. In this manner one can infer that, in case of ingestion, conditions in rumen may be favorable for transferring paraffin or other substances from the plastic debris to body fluids.

In this regard, the aim of the current research was to assess the problem of plastic ingestion in dairy cows in the central part of Ukraine in the different farm types grouped depending on the management practice and the size of the farm.

Methods

The research was conducted during 2015–2020 in Kyiv, Zhytomyr, and Cherkasy regions of Ukraine. The objects of the study were cows from 3 to 16 years of age. The presence of plastic and other IFM in the rumen was detected during diagnostic rumenotomy (Figure 1) or examination of the contents of the forestomaches at slaughterhouses and meat processing plants (Figure 2). Indications for surgery or slaughter of animals were persistent chronic dystonia of the forestomachs (atony, hypotension, and periodic tympani), conservative treatment of which was ineffective. In all cases, only primary dystonia was taken into account but not the one as a consequence of another disease.

If necessary, during the rumenotomy, manual evacuation of one-third to one-half of the rumen contents was performed, as well as magnet and manual examination of the bottom of the forestomaches and evacuation of the IFMs found inside.

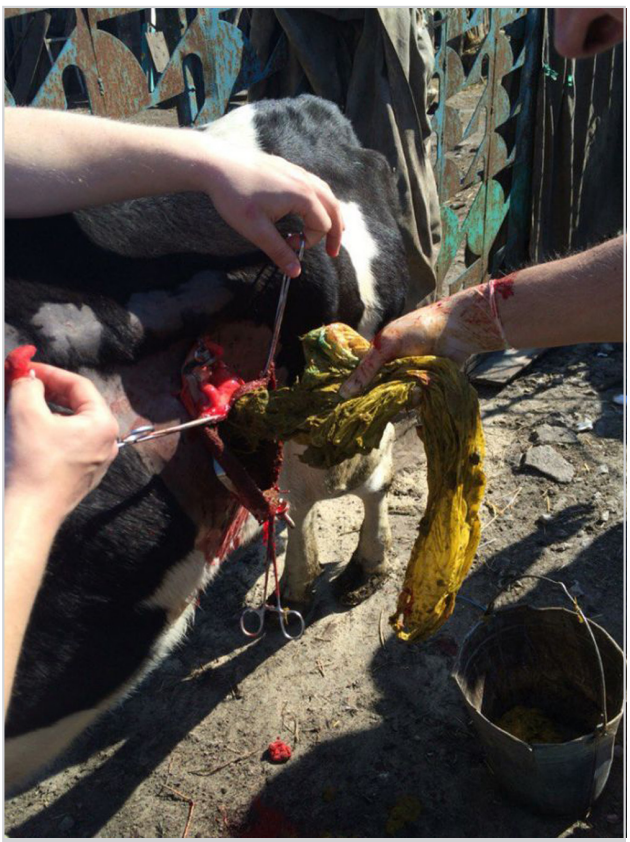

Figure 1
Removal of a Plastic Bag From a Cow's Rumen During a Rumenotomy.

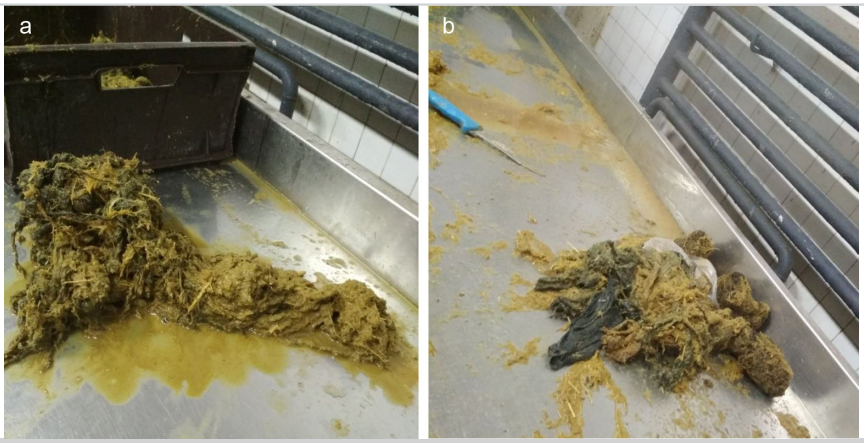

Figure 2
Conglomerates of Plastic (a, b) Found in the Rumen During the Inspection at the Meat Processing Plant.

During the analysis of the obtained data the cows were separated into different groups according to keeping conditions. First group of cows were kept at backyard farms (1–8 animals), second-on small traditional farms (usually 50–200 animals), and the third-on modern large farms with 500–1000 dairy cows.

Once the IFMs were detected in the forestomach of cows, their total number and volume were determined. In practice we were able to do it in 34 out of 39 cows with IFMs from backyard farms, 28 out of 61 from traditional, and 37 out of 73 from modern farms. The discovered foreign items in rumen content were washed with water and sorted. The volume of IFMs was determined by placing them in a plastic bucket with measured divisions that reflected the volume in liters.

In backyard farms, cows are kept indoors and mostly tied in the winter. During the summer, the cows graze on adapted pastures on the sides of roads, fields, and on the forest belts. Animals are fed with unmixed or component-fed rations-separate use of roughage, succulent ,and concentrated feed.

While in small traditional farms in the winter, cows are mainly kept indoors and tied up most of the time, and in the summer-in summer camps or stables. In some cases, cows on such farms have access to cultivated pastures combined with component-fed rations and only in some farms, mixed rations and feeding table are used.

On large modern farms, cows are kept loose indoors all year round, rest in stalls, and totally mixed rations with a feeding table are used for feeding.

Statistical Analysis

The collected data were processed in Microsoft Excel. Descriptive analysis was used to present and evaluate the obtained data. Pearson's chi-square test was used to evaluate proportions with Bonferroni correction for multiple comparisons.

Results

A total of 8790 cows from farms of different management systems were surveyed. We found that the number of cases of chronic dystonia in modern dairy farms were significantly lower than in traditional and small backyard farms ($p < .001$, Table 1).

It is also worth noting that IFMs were the main cause of chronic prolonged dystonia of forestomach in 93%, 91%, and 82% of

Table 1
Percentages of Cows with Forestomach Dystonia and Confirmed IFMs in Forestomach in Different Farm Types[1]

	Backyard		Traditional		Modern		
Item	***n***	**%**	***n***	**%**	***n***	**%**	***p***
Cows examined	815	-	2054	-	5921	-	-
Cows with forestomach dystonia	42	5.2[a]	67	3.3[b]	89	1.5[c]	<.001
Confirmed IFMs in forestomach	39	92.9[a]	61	91.0[a]	73	82.0[a]	.118

Note: [1]Farm types were: backyard farms (1–8 animals), small traditional farms (usually 50–200 animals) modern large farms (500–1000 dairy cows).
[a,b,c]Percentages in the same line with different superscripts are significantly different ($p < .05$).

Table 2

The Types of IFMs Found in Cows with Chronic Forestomach Dystonia in Different Farm Types[1]

	Backyard		Traditional		Modern		
Item	***n***	**%**	***n***	**%**	***n***	**%**	***p***
Examined cows with IFMs	34	-	28	-	37	-	-
Types of IFM							
Invasive metal	2	5.9[a]	3	10.7[a]	1	2.7[a]	.407
Non-invasive metal	13	38.2	14	50.0	9	24.3	.099
Nylon rope and bale net	25	73.5[a]	28	100.0[b]	37	100.0[b]	<.001
Polyethylene film for silage and haulage sealing	-	-	8	28.6[a]	5	17.9[a]	.133
Package material from veterinary and other supply	-	-	5	17.9[a]	4	10.8[a]	.415
Pieces of synthetic clothing	11	32.4[a]	2	7.1[b]	-	-	.015
Household plastic bags and packages	15	44.1[a]	2	7.1[b]	-	-	.0011
Other materials (rubber, stones, etc.)	5	14.7[a]	3	10.7[a]	3	8.1[a]	.675

Note: [1]Farm types were: backyard farms (1–8 animals), small traditional farms (usually 50–200 animals) modern large farms (500–1000 dairy cows).
[a,b,c]Percentages in the same line with different superscripts are significantly different ($p < .05$).

cases on backyard, traditional, and modern dairy farms, respectively (Table 1).

A smaller proportion of the cows had only one type of IFMs in forestomach. The majority of cows had two or more types of foreign material (Table 2). Nylon ropes, bale nets, household plastic bags, food packaging material, and items of synthetic clothing and rags were most frequently foun d in cows from backyard farms. Non-invasive metal items, nylon ropes and bale nets, polyethylene films for sealing silage and haylage, and plastic packaging film from veterinary products were the most frequent items found in cows from traditional and modern farms. Nylon ropes and bale nets were significantly more frequent in traditional and modern farms compared to backyard farms ($p < .001$). Pieces of synthetic clothing and household plastic bags and packages were most often found in backyard farms and rarely in traditional farms ($p = .015$ and $p < .001$, respectively), and were not found in modern farms at all. In all animals, metallic ferromagnetic materials and stones were mostly localized in the reticulum (at the bottom), and plastic and rubber were mostly located in the rumen.

Examination of the structure of IFMs found in the forestomach showed that very often the nylon ropes and mesh, household bags and even polyethylene films formed conglomerates of different shapes and sizes (Table 3). Conglomerates of small (<1 L), medium (1–3 L), and large (>3 L) sizes were found in affected cows from backyard farms, while on both other farms only small and medium conglomerates of indigestible materials were detected. The relative quantities of small and large sizes conglomerates were significantly different between the farm types ($p < .001$), with small conglomerates being more common in modern farms, while big conglomerates being only present in backyard farms.

Table 3

Detection of Different Sizes of Plastic Conglomerates in Cows with Chronic Forestomach Dystonia in Different Farm Types[1]

	Backyard		Traditional		Modern		***p***
Item	***n***	**%**	***n***	**%**	***n***	**%**	
Examined cows with IFMs	34	-	28	-	37	-	-
Size of the detected plastic conglomerates							
Small (up to 1 L)	11	32.4[a]	15	53.6[a,b]	26	70.3[b]	<.001
Middle (from 1 to 3 L)	16	47.1[a]	13	46.4[a]	11	29.7[a]	
Big (more than 3 L)	7	20.6	-	-	-	-	

Note: [1]Farm types were: backyard farms (1–8 animals), small traditional farms (usually 50–200 animals) modern large farms (500–1000 dairy cows).
[a,b,c]Percentages in the same line with different superscripts are significantly different ($p < .05$).

Discussion, Conclusion and Recommendations

For decades, plastic has been used for the functional study of the gastrointestinal tract in ruminants. Plastic balls or bags are used to study excretion rate and rumination (Seyama et al., 2017), and feed degradation measurements (Pagella et al., 2018). Plastic ribbons and filaments of different diameters, hardness, and specific gravities were found useful in measuring rumination and passage events (Welch, 1990).

In the recent years, the problem of "accidental," "intentional" or "voluntary" plastic ingestion by animals has taken growing research interest. The findings of Savoca et al. (2017) provide support for a chemosensory mechanism underlying plastic consumption by animals. It was found that fishes respond to plastic debris odor with increased aggregation and reduced rheotaxis that is typical reaction on food or food odor. Data obtained by Andrades et al. (2019) indicate that scavenging behavior may be an important cause for plastic ingestion by animals. The authors investigated the relationship between scavenging behavior and plastic ingestion in green turtles. They found that turtles engaging in scavenging behavior ingested considerably more plastic debris than those that did not use this foraging habit. Santos et al. (2016) noted that in recent years plastic ingestion is attributed to color similarities of plastic debris to animal's usual food. Though the authors also acknowledge that this explanation is not always in accordance with the assortment of plastic pieces ingested and the species main ration items.

Noting little progress in understanding of the factors that cause susceptibilities to plastic ingestion Machovsky-Capuska et al. (2019) proposed the usage of principles of nutritional ecology as interdisciplinary framework that combine approaches of ecology, physiology, nutrition, and animal behavior with the issue of plastic ingestion.

Our own longtime experience of work with various dairy farms, slaughterhouses, and meat processing plants has shown that the level of forestomach contamination by foreign bodies in cattle increased significantly. In this study, there were cows monitored with forestomach dysfunction. We found that the number of cases when veterinarians treat forestomach dystonia or tympani with a short-term positive result or no results at all depends on the size of the farm. Smaller farms that use uncultivated natural pastures have 5.15% of cows with affected forestomach dystonia. Big modern farms with limited use of good cultivated pastures have only 1.5% of cows with chronic forestomach dysfunction. Eventually, the affected cows are sent to sanitary slaughter, during which foreign bodies are found in the rumen.

In general, the management of plastic rumen impaction poses a clinical problem as diagnosing and treatment of forestomach diseases is often a challenging task (Braun et al., 2018). Currently many researchers refer to exploratory rumenotomy as the only means for both diagnosing and treatment of rumen impaction with plastic materials (Hartnack et al., 2015; Niehaus, 2008). Animals undergoing rumenotomy mostly have a favorable and fair prognosis for survival and potential return to production. In this study in a number of cases, the rumenotomy was performed during which foreign bodies were removed from the rumen.

In our opinion the lowest level of cows with chronic forestomach dysfunction on the big modern dairy farms is explained by the fact that there is a more careful control over the technological processes of harvesting, storage and processing of the feedstuff (hay, silage, haylage, concentrates), and bedding material (straw etc.), thus preventing swallowing IFMs by animals.

On the other hand, the cows from the backyard farms and to some extent from traditional farms often use uncultivated pastures (Figure 3) and homemade rations which may be contaminated with plastic bags and household waste. Also, both baled and non-baled hay and straw are usually widely used on such farms (Figure 4a-c), and therefore in many animals nylon ropes or nets were found in the rumen.

Thus, the mentioned circumstances lead to certain similarities and differences in the sort of foreign bodies found in the forestomach of cows. The similarity was that on farms of all levels of management, the vast majority of animals had plastic as a main foreign body in the rumen. The difference was as follows: nylon ropes or bale nets were found in all cows in modern and traditional farms and in three-fourth of animals from domestic farms; polyethylene film for silage and haylage sealing, as well as packaging polyethylene films from veterinary products were found in most animals of modern and traditional farms, but not in cows from backyard farms; the pieces of synthetic clothing, rags, and household plastic bags and packaging were found in a large number in cows on backyard farms and in a small number in cows from traditional farms, but there were no such cases registered in cows on modern farms. In our opinion, these differences are due to the management features which

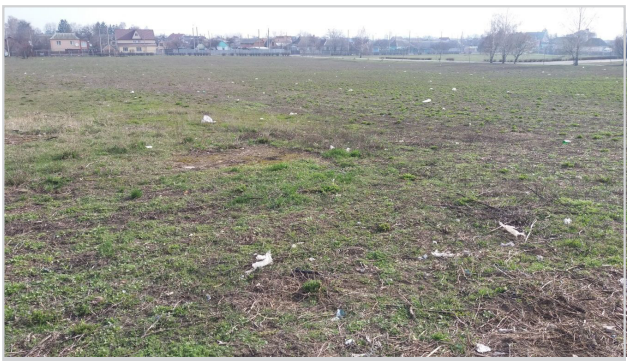

Figure 3
Contamination of Pastures with Plastic.

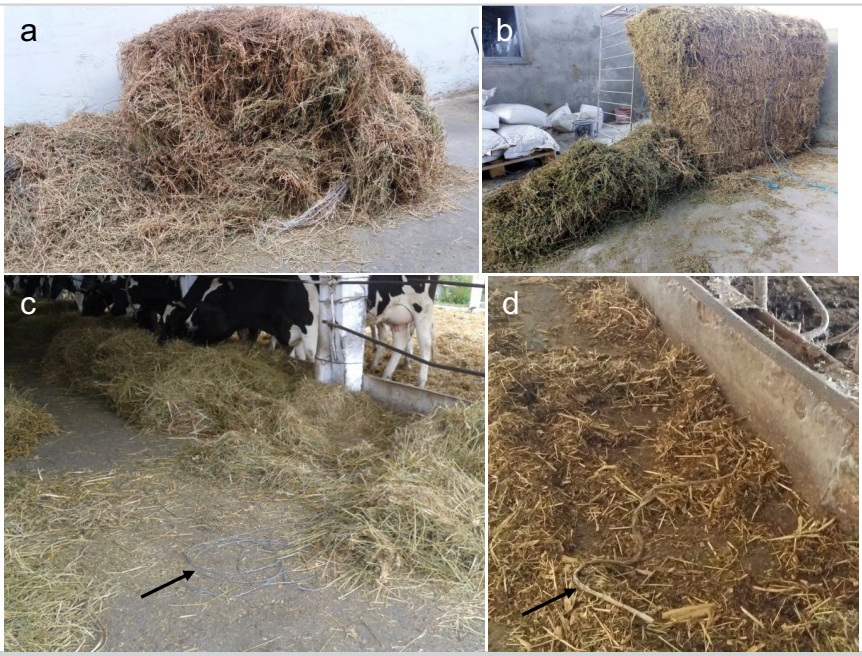

Figure 4
Nylon Ropes (→) Found on Baled Hay (a, b) and the Feed Tables (c, d) on Traditional and Modern Farms.

determine the possibility of animals' access to the relevant indigestible materials.

The results of the research conducted by other authors mostly support our findings as to plastic material and its derivates prevailing in dairy cows forestomach. Many of them also mention sex, age, and some others differences as to indigestible foreign bodies number and distribution. A study conducted by Negash et al. (2015) showed that plastic was the most commonly found foreign body (79.2%), followed by pieces of cloth (15.3%) and ropes (12.3%). Metal objects (.9%) and stone-like substances (1.0%) were also detected in the reticulum of affected animals. The aim of the research done by Mushonga et al. (2015) was to study the occurrence of foreign materials in forestomach of slaughtered cattle. The authors found that plastic was most present (65.0%) in cattle forestomach with increasing quantity of indigestible pieces in older animals and that the female cattle have a higher prevalence of foreign materials (20.0%) than males (15.7%).

Bwatota et al. (2018) examined 387 slaughter cattles for the presence of indigestible foreign bodies. The foreign materials in forestomach were found in 24.03% of studied animals. The materials were represented mainly by plastic bags, clothing and leather debris, ropes, metallic nails, hairballs, stones and wire, with plastic bags observed most frequently (50.5%).

While emphasizing the seriousness of proper plastic waste management, it is also important to consider that feeding preferences and strength of voluntary intake stimulation may be an important cause of foreign body ingestion in cattle. Lombardi et al. (2015) compared voluntary intake and preference of dairy cows for fresh and stored forages and found that cows showed an overall preference toward baled compared to fresh forages. Hence one can suggest that longer time and quicker speed of eating of baled (previously covered with at least six layers of plastic material) forages can be one of the important factors promoting plastic and others indigestible foreign bodies ingestion. Also, the increased milk yield and its component quality imply that the cows are compelled to increase their time spent feeding, to have more frequent meals, and to prolong time spent ruminating (Johnston & DeVries, 2018). Similar changes of eating behavior that facilitate the ingestion of foreign bodies may as well depend on competition situation. Studying the effects of different levels of competition for feed access in dairy cows Crossley et al. (2017) found that the greater competition resulted in a reduction of feeding time and an increased rate of feed intake especially following fresh feed delivery and milking procedure. The authors also emphasized that meal patterns vary greatly within groups of cows with high levels of competition for feed access. The latter findings may explain the fact that the cows kept in seemingly identical conditions differ in quantity and nature of indigestible foreign bodies in their forestomach.

Our results also emphasize the difference found in the size of conglomerates of plastic materials from the forestomach of affected cows ($p < .001$). Small and rarely medium conglomerates were found on big modern farms. Small and medium conglomerates were found on traditional farms in almost equal number. Mostly medium, rarely small, and large pieces

of bounded plastic were registered in cows from backyard farms. In our opinion, these findings are due not only to the number and size of IFMs but also to the time they stay in the forestomach. In this case one can suggest that the size of IFM conglomerates in the forestomach may be determined by the age of the animals-the older it is, the more plastic it can accumulate in the rumen, and large conglomerates may be formed. And as observations show, it is on backyard farms where older cows usually are kept, while on modern farms-mostly young and middle-aged ones.

Our study shows that plastic pollution is posing the global threat to the environment. The life and welfare of both, wild and domestic animals are endangered. Plastic materials and their derivates are the main component of indigestible foreign bodies found in cows' forestomach. Big pieces of plastic and conglomerates with plastic material cause a chronic prolonged forestomach dystonia in dairy cows in 92.86%, 91.04%, and 82.02% of cases on backyard, traditional, and modern dairy farms, respectively. Nylon ropes, bale nets, household plastic bags, packaging material, pieces of synthetic clothing, and rags were most frequently found in cows from backyard farms. Metal items, nylon ropes and bale nets, polyethylene films for fodder sealing, and plastic medicine packaging were the most frequent items found in cows from traditional and modern farms. Proper plastic waste management on the farms has to be an integral part of preventing forestomach diseases, decreasing culling rate, and increasing level of welfare of dairy cows.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Bila Tserkva National Agrarian University (Date: February 2015, Approval No: 15/014).

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Author Contributions: Concept – A.Y., V.K.; Design – N.K., V.K.; Supervision – V.K., M.C.; Materials – O.E.; Data Collection and/or Processing – A.Y., M.C., O.E., O.P.; Analysis and/or Interpretation – A.Y., V.S., O.P.; Writing Manuscript – N.K., L.S.; Critical Review – L.S., V.S.

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