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MARYLA BIENIEK-MAJKA[1]

Kazimierz Wielki University in Bydgoszcz, Poland

EVALUATION OF LOSSES AT THE PRIMARY PRODUCTION STAGE OF EDIBLE CARROTS

Key words: food waste, food losses, primary production, vegetables, edible carrots

ABSTRACT. The aim of the article is to present the magnitude of losses at the stage of primary edible carrot production and to indicate directions for redistributing production waste. The study included producers of edible carrots located in the Kuyavian-Pomeranian Voivodeship, whose average yield size in the years 2019-2021 corresponded to 15% of the total yield collected in the voivodeship and approximately 2.4% in the country. Based on expert interviews and commercial documentation analysis, it was found that, due to high customer demands regarding the appearance of carrots ("cosmetic standards"), on average, only about 44% of the weight of calibrated carrots intended for sale constituted the mass of the harvested raw material. Approximately 7% was allocated to processing plants, and around 26% of the raw material mass was used for animal feed. The remaining portion of the harvest represented production losses (19%) and fuel for biogas plants (4%). In order to reduce production losses, primarily resulting from the depreciation of items solely based on their appearance, recipients (e.g., retail chains) should enable producers to deliver less visually appealing raw materials with corresponding price discounts. It is also crucial to raise awareness among customers through educational and promotional efforts, emphasizing the equal nutritional value of raw materials regardless of their appearance (straight, curved, thicker, thinner). This will increase both the product's availability to the public and production efficiency for the producer.

[1] Corresponding author: maryla@ukw.edu.pl

INTRODUCTION

According to projections, the world's population may increase to approximately 9.7 billion by the year 2050. With this population growth, the demand for food is also expected to rise. According to FAO [2022], it is estimated that in order to meet food needs, food production would need to increase by about 70% compared to the levels in 2009 by the year 2050. However, this increase in food production comes with significant environmental costs, as agriculture has a substantial impact on soil quality and ecosystems. It is also responsible for over one-third of greenhouse gas emissions and consumes around 70% of freshwater resources. Estimates suggest that the rejection of vegetables and fruits based on "cosmetic standards" leads to food waste, and in Europe, it accounts for the emission of 22,500 kt CO_{2e} of greenhouse gasses annually during the production phase [Porter et al. 2018].

Climate changes contribute to reducing yields and the nutritional content of plant-based products. According to goal 12.3 of Agenda 2030 [ONZ 2015], the global per capita food waste at the retail and consumer levels must be halved by 2030, along with reducing food losses in production and distribution, including post-harvest losses. Under the conditions of climate change and food security threats, neglecting the magnitude of food losses is unjustifiable, and it is necessary to strive for minimizing losses wherever possible. Actions aimed at reducing food waste should be implemented at the micro level, and the cumulative results of waste reduction by individual producers will shape global success.

When organizing the definitions of food losses and waste that occur throughout the agricultural and food supply chain, from primary production to consumption, it is assumed that food losses mainly occur in the initial stages of the chain, rendering the edible portion of raw materials unavailable for human consumption. On the other hand, food waste is primarily attributed to distributors and consumers, who often knowingly discard food products that are still fit for consumption [Łaba 2020, p. 12-13] (Figure 1).

According to Małgorzata Wiśniewska and Joanna Wyrwa [2022], food losses occur in various stages, including agricultural production, storage, transportation, and

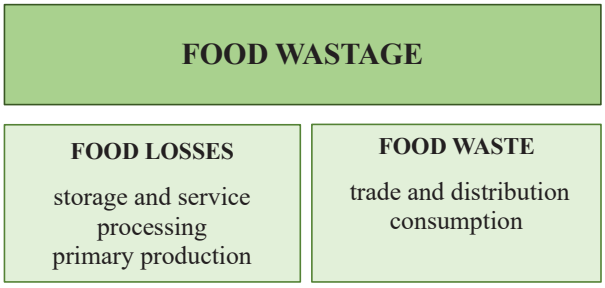

Figure 1. Classification of concepts related to food wastage
Source: [Łaba 2020, p. 13]

processing of agricultural products. These losses are particularly prevalent in developing countries, where technical limitations (such as inadequate infrastructure for storage or the transportation of agricultural produce) and technological constraints (resulting from irregularities in processing procedures) often exist, along with insufficient knowledge regarding food production, processing, and storage methods. The authors suggest that errors during the production and storage processes contribute to approximately 40% of food losses. Conversely, in developed countries, the proportion of losses is lower due to the implementation of modern production techniques and systems that monitor the flow of agricultural products. However, increased food waste is observed in these countries at later stages of the agricultural and food supply chain, primarily during distribution (e.g., products not meeting retail standards) and consumption (e.g., food not consumed before the expiration date).

Food losses at the initial stage of the supply chain can be caused by internal and external factors. Internal factors, which the farmer has direct control over, include improper production, storage, transportation, and processing of agricultural products. They can also result from unfavourable agreements made by the producer with product recipients. On the other hand, external factors, over which the farmer has little or no control, may include weather conditions, plant diseases, a decline in market demand, and the reliability of machinery and technology [Niedek et al. 2019].

Primary agricultural production is the first link in the agricultural and food supply chain, where like in other links, food losses occur. Research conducted in Polish farms in 2019 by Sylwia Łaba et al. [2020] revealed varying levels of losses depending on the type of agricultural production. The average losses in weight per household ranged from 0.31 tons in rapeseed production to 3.83 tons in fruit and vegetable production, which represents several times more losses. As the fruit and vegetable sector experiences the highest losses compared to other types of agricultural production, edible carrots were selected for assessing these losses, being one of the fundamental vegetables consumed by the population.

MATERIAL AND RESEARCH METHODS

The aim of this article is to present the extent of losses during the primary production stage of edible carrots and to identify directions for redistributing production waste. The research methods employed in this study included expert interviews and an analysis of accounting documentation. Interviews with producers of edible carrots from the Kuyavian-Pomeranian Voivodeship were conducted in January 2023. The source material consisted of warehouse and sales documentation for the years 2019-2022, encompassing accounting documents such as Purchase Orders (PW), Sales Orders (RW), Delivery Notes (WZ),

and Invoices (FS). The study focused on seven purposely selected producers, whose aggregated carrot harvest in 2021 accounted for approximately 15% of the total harvest in the Kuyavian-Pomeranian Voivodeship and around 2.8% in the entire country. The surveyed producers had modernized storage facilities, production lines, and refrigerated trucks with trailers. The cultivation of edible carrots and the preparation process for sale were conducted in accordance with GlobalGAP guidelines. Possessing this certification enabled collaboration with retail chains, where it is a necessary requirement.

The extent of losses was presented using a mass balance approach [Niedek et al. 2019], which involves calculating the proportion of the mass of finished products to the mass of raw materials destined for sale as raw material for processing or animal feed, based on the total mass of the received raw material (i.e., carrots collected from the fields and accepted into the storage warehouse).

Losses = mass of finished products + mass of raw materials for sale (raw material for processing + animal feed) / mass of raw materials accepted into the storage warehouse

The utilization of carrot yields was presented as a structure employing percentage indicators, that is, the proportions of carrot mass according to various methods of utilization in the total raw material mass harvested from the fields. The following types of carrots were distinguished: calibrated consumption carrots, carrots for processing as raw material, carrots for fodder, and waste designated for biogas plants.

RESULTS OF RESEARCH

Poland is among the leading European producers of edible carrots, with an average production of approximately 666,000 tons in the years 2019-2021. Apart from Poland, the largest producers of edible carrots in Europe are the United Kingdom and Germany, with production amounts of approximately 758,000 and 791,000 tons in 2019, respectively [GUS 2020].

The vegetable cultivation area in Poland decreased from 176,400 hectares to 164,300 hectares during the years 2019-2021, including the area designated for cultivating edible carrots, which reduced from 22,200 hectares in 2019 to 17,500 hectares in 2021. However, in the Kuyavian-Pomeranian voivodeship, the vegetable cultivation area increased by approximately 2,000 hectares, and the share of the area dedicated to vegetable cultivation rose by 2 percentage points.

In 2021, edible carrots were grown on approximately 10.7% of the total vegetable cultivation area in Poland, and in the Kuyavian-Pomeranian Voivodeship, they were grown

on 12.2% of the total vegetable cultivation area. Despite the decrease in the area dedicated to vegetable production, there was an increase in overall vegetable harvest size during the study period, from 5,019,000 tons in 2019 to 5,279,000 tons in 2021. Unfortunately, the same trend was not observed for the harvest of edible carrots, as it decreased from 679,000 tons in 2019 to 638,000 tons in 2021. The harvest of edible carrots in 2021 accounted for 16.4% of all vegetable harvests in Poland, and 18.5% in the Kuyavian-Pomeranian Voivodeship [GUS 2022].

For the surveyed producers in the Kuyavian-Pomeranian Voivodeship, the size of the edible carrot harvest increased from 14,700 tons to 17,800 tons in the years 2019-2021, representing approximately 15% of vegetable harvests in the Kuyavian-Pomeranian Voivodeship and 2.8% in the whole country in 2021.

The gathered raw material was subjected to storage in refrigerated warehouses. Subsequently, depending on the volume of incoming customer orders, the carrots were successively washed, brushed, calibrated, packed, and transported to the clients. The main recipients of the finished product are retail chains and wholesalers. Due to the requirements set by customers, known as "cosmetic standards" in the subject literature [Porter et al., 2018] (dictated by the expectations of end consumers), which mainly pertain to carrot parameters (50-250 g, diameter 2-4 cm), a portion of the raw material with full nutritional properties is rejected as not meeting commercial norms. The sorted carrots are then divided by size, below and above the commercial standard. Raw material exceeding the standard size may be desired by processing plants, while small carrots can be used as feed for livestock (primarily for cattle) as well as wild animals (supplied to forestry and zoological gardens). Carrots showing signs of decay and greening are sent to biogas plants.

The mass balance of carrots, established based on storage and trade documentation for the surveyed farms, indicated that during the production phase (from storage warehouses through washing, calibration, packing, and transportation to the warehouse of finished products), raw material losses averaged around 19%. These losses resulted from natural drying processes in the cold storage, losses during internal transportation, and the preparation process for sale. Calibrated carrots intended for final consumers accounted for on average of only about 44% of the gathered raw material mass, while the portion of gathered raw material intended for processing amounted to on average of about 7% of the total mass. Based on this data, it can be concluded that just over half of the gathered raw material was intended for human consumption, while the rest comprised feed for animals (averaging around 26% of the gathered raw material mass) or fuel for biogas plants (averaging around 4%) (see Figure 2).

Analysing the trade documentation (after subtracting production losses) of the surveyed producers of edible carrots, it can be observed that the proportion of calibrated product sales, meeting consumer expectations, averaged around 54% of the total sales mass (Table 1). The remaining portion of carrots was sold as a lower-value product. The main

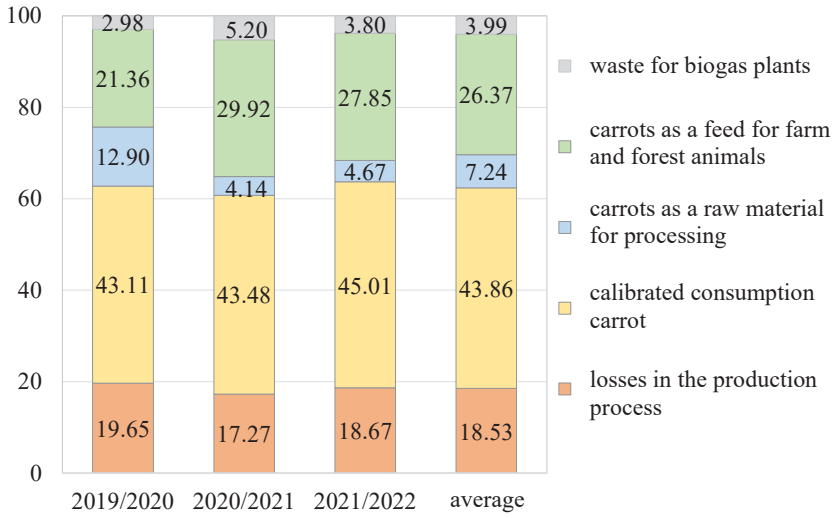

Figure 2. Structure of carrot yields based on utilization method
Source: own study

recipients of this full value, but not meeting commercial criteria, carrots were agricultural farms (engaged in cattle breeding), forestry authorities, and zoological gardens. These buyers purchased an average of about 70% of the mass of carrots rejected due to their size during the study period.

Another recipient of carrots that did not meet commercial standards was processing plants. However, due to the specific nature of the production process (processing specific vegetables only during certain times), they did not systematically collect the raw material. Additionally, processing plants also have requirements regarding the calibration of the raw material, and not all sorted carrots meet these requirements (e.g., diameter above 4 cm).

In the 2019/2020 season, processing plants collected over one-third of the sorted edible carrots from the surveyed producers. This season had the highest purchase and retail prices during the study period (Table 2), indicating that processing plants might have been seeking new suppliers and negotiating price conditions with them. The average share of processing plants in the total mass of sold carrots that did not meet commercial criteria during the study period was about 20%. The remaining portion of sorted carrots (about 10%) was utilized as fuel in biogas plants, meaning it was not intended for food for either humans or animals.

Partially, the magnitude of production losses is determined by factors independent of humans. In Poland, in recent years, there have been several situations where the raw

Table 1. Structure of carrot sales according to purpose

Designation	Share [%]			Average	Standard deviation
	2019/2020	2020/2021	2021/2022		
Calibrated consumption carrots	53.65	52.55	55.35	53.85	1.41
Sorted carrots for sale, including:	46.35	47.45	44.65	46.15	1.41
–carrots as raw material for processing	34.65	10.54	12.86	19.35	13.30
–carrots for animal feed	57.34	76.21	76.69	70.08	11.04
–waste for biogas plants	8.01	13.25	10.45	10.57	2.62

Source: own research

Table 2. Wholesale and Retail Prices of Carrots in the years 2019-2021

Specification	Yearly values		
	2019	2020	2021
Average wholesale price of carrots [PLN/kg]	0.53	0.43	0.49
Average retail price of carrots [PLN/kg]	2.96	2.83	2.87
Retail price/wholesale price	5.58	6.58	5.86

Source: own elaboration based on [GUS 2022, p. 256, 275]

material lost its appealing appearance mainly due to weather conditions[2] (e.g., beets, cabbage, carrots). "It is a sad sign of our times that we prefer something to go to waste rather than looking unappealing", wrote the author of an article on beets and cabbage that did not meet the criteria of retail chains and processing plants [HAPS 2021]. This was also confirmed by a producer of edible carrots, whom the retail chain assisted in selling non-calibrated produce [Portal Spożywczy 2021].

Retail chains often emphasize that they are socially responsible institutions, and combating food waste is one of their most important activities. They conduct one-time actions that help farmers reduce financial losses and increase the value of their brand. However, continuous support should be expected from them, for example, by changing the requirements related

[2] "Crooked" beets, according to the farmer growing them, are considered a seed defect, while the poorer appearance of cabbage was caused by hailstorms [Portal Spożywczy 2021].

to the calibration of agricultural products, as well as through promotional and educational initiatives that alter the perception of imperfectly looking vegetables.

A product meeting "cosmetic standards", i.e., the calibration requirements of the end consumer, represents only about half of the production volume of the raw material on average. This is reflected not only in the reduced possibility of delivering edible products to the market for consumers but also in the profitability of production. According to Joanna Michalczyk and Wawrzyniec Michalczyk [2019], obtaining lower revenue from the sale of products rejected during sorting can result in price increases, which necessitate customers to spend more on these goods, potentially limiting their access to food. The price difference between the raw material for the producer and the retail price for the end consumer is several times higher (Table 2). This surplus primarily benefits retailers. Literature on the subject [e.g., Kawecka, Gębarowski 2015] suggests shortening the supply chain to achieve a higher share of the final product price for producers.

SUMMARY

Mikołaj Niedek and Karol Krajewski [2021] stated that contemporary trends related to food losses and waste at all stages of the agri-food chain require changes in prevailing consumption patterns to align with the demands of sustainable and balanced development. Stephen D. Porter et al. [2018] and Lu Shijun et al. [2022], who investigated both the European and Chinese markets, observed that rigorous requirements and irrational consumer preferences contribute to vegetable and fruit producers taking action that lead to increased losses.

The results of conducted research revealed that due to high demands from end consumers, almost half (approximately 46%) of the full-value raw material is eliminated from sales due to aesthetic qualities ("cosmetic standards"). A small percentage of the raw material is directed to further processing stages, but the significant portion is designated as animal feed. As shown in Elżbieta Goryńska-Goldmann et al., study [2021], this is the preferred method of managing food raw material losses. The necessity to sell full-value products at lower prices, such as for animal feed, results in producers losing potential benefits, thus lowering the profitability of their operations. It is recommended, for example, that retail chains more frequently allow full-value products with lower aesthetic qualities to be sold at lower prices, not just incidentally. This could increase both society's access to food and producers' revenue. At the same time, customers should be made aware that food items with good nutritional value should not be devalued solely due to their less attractive appearance.

BIBLIOGRAPHY

FAO. 2022. *Thinking about the future of food safety – a foresight report*. Rome: FAO, https://doi.org/10.4060/cb8667en, access: 10.05.2023.

Goryńska-Goldmann Elżbieta, Michał Gazdecki, Krystyna Rejman, Joanna Kobus-Cisowska, Sylwia Łaba, Robert Łaba. 2021. How to prevent bread losses in the baking and confectionery industry? Measurement, causes, management and prevention. *Agriculture* 11 (1): 19. DOI: 10.3390/agriculture11010019.

GUS (Central Statistical Office). 2020. *Produkcja i handel zagraniczny produktami rolnymi w 2019 r.* (Production and foreign trade of agricultural products in 2019). Warszawa: GUS.

GUS (Central Statistical Office). 2022. *Rocznik statystyczny rolnictwa 2022* (Statistical Yearbook of Agriculture 2022). Warszawa: GUS.

HAPS. 2021. *Były krzywe buraki, pora na sfatygowaną kapustę. Sieciówka odkupi warzywa po gradobiciu* (There were crooked beets, time for battered cabbage. A retail chain will purchase the vegetables after hail), https://haps.pl/Haps/7,167709,27179271,byly-krzywe-buraki-pora-na-sfatygowana-kapuste-sieciowka-odkupi.html, access 01.05.2023.

Kawecka Agnieszka, Marcin Gębarowski. 2015. Short food supply chains – benefits for consumers and food producers. *Journal of Agribusiness and Rural Development* 37 (3): 459-466. DOI: 10.17306/JARD.2015.49.

Łaba Sylwia (ed). 2020. *Straty i marnotrawstwo żywności w Polsce. Skala i przyczyny problemu* (Food losses and waste in Poland. Scale and sources of the problem). Warszawa: Instytut Ochrony Środowiska – Państwowy Instytut Badawczy.

Łaba Sylwia, Beata Bilska, Marzena Tomaszewska, Robert Łaba, Krystian Szczepański, Agnieszka Tul-Krzyszczuk, Małgorzata Kosicka-Gębska, Danuta Kołożyn-Krajewska. 2020. Próba oszacowania strat i marnotrawstwa żywności w Polsce (An attempt to estimate losses and food waste in Poland). *Przemysł Spożywczy* 74: 10-18. DOI: 10.15199/65.2020.11.2.

Michalczyk Joanna, Wawrzyniec Michalczyk. 2019. Problem marnotrawstwa i strat wobec zachowania bezpieczeństwa żywnościowego w ujęciu międzynarodowym (The problem of waste and loss in the face of maintaining food security at the international level). *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu* 63 (3): 50-69. DOI: 10.15611/pn.2019.3.05.

Niedek Mikołaj, Karol Krajewski. 2021. Problematyka marnowania żywności w Polsce, a kształtowanie wzorca zrównoważonej konsumpcji (The Problem of Food Wasting in Poland and Shaping the Pattern of Sustainable Consumption). *Studia Ecologiae et Bioethicae* 19 (2): 17-28. DOI: 10.21697/seb.2021.19.2.02.

Niedek Mikołaj, Sylwia Łaba, Krystian Szczepański, Karol Krajewski. 2019. Metody ilościowe w badaniu strat i marnotrawstwa żywności w sektorze produkcji pierwotnej (Quantitative research methods in the case of food losses and waste in primary production sector). *Metody Ilościowe w Badaniach Ekonomicznych* XX (4): 263-279. DOI: 10.22630/MIBE.2019.20.4.25.

ONZ (Organizacja Narodów Zjednoczonych, United Nations). 2015. Rezolucja „*Przekształcamy nasz świat. Agenda na rzecz zrównoważonego rozwoju 2030*". (Resolution „Transforming our world. The 2030 Agenda for Sustainable Development"). Resolution UN, A/RES/70/1, 25.09.2015.

Portal Spożywczy. 2021. Lidl: po krzywych burakach sprzedaje krzywe marchewki (*Lidl: selling crooked carrots after crooked beets*), https://www.portalspozywczy.pl/handel/wiadomosci/lidl-po-krzywych-burakach-sprzedaje-krzywe-marchewki,206032.html, access: 01.05.2023.

Porter Stephen D., David S. Reay, Elizabeth Bomberg, Peter Higgins. 2018. Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK, *Journal of Cleaner Production*. DOI: 10.1016/j.jclepro.2018.08.079.

Shijun Lu, Guangyan Cheng, Tai Li, Li Xue, Xiaojie Liu, Jiazhang Huang, Gang Liu. 2022. Quantifying supply chain food loss in China with primary data: A large-scale, field-survey based analysis for staple food, vegetables, and fruits. *Resources, Conservation and Recycling* 177. DOI: 10.1016/j.resconrec.2021.106006.

Wiśniewska Małgorzata Z., Joanna Wyrwa. 2022. *Bezpieczeństwo żywności i żywnościowe w okresie pandemii. Ujęcie interdyscyplinarne* (Food an eatables security during the pandemic. Interdisciplinary approach). Zielona Góra: Polskie Towarzystwo Ekonomiczne.

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OCENA STRAT NA ETAPIE PRODUKCJI PODSTAWOWEJ MARCHWI JADALNEJ

Słowa kluczowe: marnotrawstwo żywności, straty żywności, produkcja podstawowa, warzywa, marchew jadalna

ABSTRAKT. Celem artykułu jest przedstawienie wielkości strat na etapie produkcji podstawowej marchwi jadalnej oraz wskazanie kierunków rozdystrybuowania odpadów produkcyjnych. Badaniem objęto producentów marchwi jadalnej zlokalizowanych w województwie kujawsko-pomorskim, których średnia wielkość zbiorów w latach 2019-2021 odpowiadała 15% wielkości zebranej masy w województwie i około 2,4% w kraju. Na podstawie wywiadów eksperckich oraz analizy dokumentacji handlowej stwierdzono, że ze względu na wysokie wymagania klientów co do wyglądu marchwi (ang. *cosmetic standards*), średnio masa marchwi wykalibrowanej przeznaczonej do sprzedaży stanowiła tylko około 44% masy zebranego surowca. Do zakładów przetwórczych przeznaczano średnio około 7%, a na paszę dla zwierząt około 26% masy surowca. Pozostała część zbiorów to straty produkcyjne (19%) i paliwo do biogazowni (4%). W celu zmniejszenia strat produkcyjnych, wynikających przede wszystkim z deprecjonowania artykułów tylko ze względu na ich wygląd, odbiorcy (np. sieci handlowe) powinni umożliwić producentom dostarczanie mniej atrakcyjnych pod względem wyglądu surowców, z uwzględnieniem upustów cenowych. Ważne jest także uświadamianie klientów za pomocą działań edukacyjnych i promocyjnych, na temat takiej samej wartości odżywczej surowca – bez względu na jego wygląd (prosty, krzywy, grubszy, drobniejszy), co służyć będzie zwiększeniu zarówno dostępności produktu dla społeczeństwa, jak i efektywności produkcji dla producenta.

AUTHOR

MARYLA BIENIEK-MAJKA, PHD

ORCID: 0000-0003-1448-7406
Kazimierz Wielki University in Bydgoszcz
Department of Law and Economy
e-mail: maryla@ukw.edu.pl

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