

TECHNOLOGICAL AND MARKET ASPECTS OF VEGETABLE PRODUCTION ON A FARM

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Purpose: The article analyzes the market for technologies used to support production processes in directed agriculture. The state of vegetable farming in Poland was analyzed and references were made to the country's market and economic potential in relation to vegetable cultivation. Also analyzed were the directions of distribution of vegetables on a national and international scale. The vegetable farm surveyed in the case study has been cooperating with a chain of super and hyper markets for several decades.

Design/methodology/approach: The subject of observation and profitability assessment included industry reports, technological flowcharts and price calculation using methods of calculating the arithmetic mean based on VAT invoices provided by the surveyed business entity. The presentation and detailed examination of available data took the form of tables and bar charts which were justified descriptively. The source of information for this paper was the subject literature, statistical data and many studies of the Central Statistical Office and Eurostat, reports in the industry section, an interview with the owner of a vegetable farm, an analysis of financial documents made available by the business in question as well as the author's own observation. The business's characteristics, revenues, costs and sales market were examined. Also, the machine park of the surveyed business and the level of employment therein were analyzed over the years.

Findings: The surveyed farm produces goods for over 10 months a year, which significantly affects the continuity of supplying the customer with fresh vegetables. The article presents the characteristics of the farm and analyzes the production possibilities for individual vegetables. Manufacturing large quantities of goods requires an adequate supply of warehouse space, vegetable processing halls and the necessary human resources. The surveyed farm has been recording a steady increase in investment opportunities as well as introduction and improvement of recycling and ecological activities.

Research limitations/implications: The analysis was limited to one vegetable farm.

Keywords: cost, production, agricultural machinery, cultivation, tractor.

Category of the paper: research paper.

1. Introduction

One of the most dynamically developing market sectors in the country is the food market (Dzudzor, Gerber, 2023). Part of this sector is the production and sale of vegetables on a large scale (Scur et al., 2023). A number of changes regarding vegetable production were initiated mainly as a result of Poland's accession to the European Union (Santeramo et al., 2021; Bielska et al., 2023). Numerous legal and technological regulations have since been introduced to increase the quality and safety standards of goods and the environment. The adopted legislation requires producers to carry out appropriate organization, investments and technological modernization (Witczak et al., 2018; Kowalczyk, Cupiał, 2020). The fruit and vegetable market in Poland is covered by the regulations of the Common Organization of the Fruit and Vegetable Market (COFVM), which was established in 1996 in the European Union (COFVM, 2023).

Wholesale markets are an important part of the institutional infrastructure of the horticultural market – they refer to the network of entities located in Poland that organize trade in food and horticultural goods (Fałkowski, Chlebicka, 2021). The wholesale market can be run by concentrating trade turnovers, which means locating them in a specific place (Dan et al., 2023). They take the form of organized markets, where transactions are concluded between sellers and buyers. By way of the organization of the existing wholesale market system, the markets were divided into cross-regional, regional and local markets (Gołębiewski, Sobczak, 2017). This measure was aimed at introducing an orderly market system and increasing the availability of goods. Considering the specificity of the vegetable-oriented agricultural sector, the issue of export and import of vegetables cannot be ignored (Duque-Acevedo et al., 2022). The introduction of the unification of countries as well as the implementation of appropriate policies between the countries of the world have both contributed to a significant development of product imports on the market. The society's ever-increasing demand for vegetables contributes to the development of competitiveness on the market. The domestic vegetable production is at a relatively high level, compared to other European Union countries. Over recent years, Poland has seen an increase in the area of cultivation and the volume of vegetable harvest. In 2021, Poland was one of the leading countries producing onions and carrots (GUS, 2021). Management of vegetable farms is largely determined by the quality and extent of mechanization of a given production unit as well as the human workload. By way of the gradual introduction of automatic solutions, the number of people employed on farms can be significantly reduced and the cultivated area can be increased. The main aspect of production is the level of consumerism and demand, especially in Poland, but also as its exports abroad. Some of the factors that affect the significant volume and quality of the product include the climate, soil and atmospheric conditions. An important aspect is ensuring proper fertilization, i.e. providing vegetables with the necessary minerals and nutrients, which significantly improves the yield per hectare. Proper fertilization also replaces natural climatic, atmospheric

and soil factors, to a certain extent. The continuous development and purchase of equipment improve the status and importance of the farm on the market. Farmers willingly choose multi-task machines to be able to use the equipment as efficiently as possible, with optimal investment spending.

2. Current state of the fruit and vegetable industry

63 million tons of all vegetables were harvested in the EU countries (EU-27) in 2022; in the previous year (2021), the harvest was 65.7 million tons (EU, 2022, Annual activity report, 2022). Based on data provided by the Central Statistical Office (GUS – Główny Urząd Statystyczny) in 2018, over 150 thousand hectares were sown with vegetables, while the number of individual farms was 58,626. In 2021, the total area of vegetable cultivation in Poland amounted to 169.5 thousand hectares. In 2022 it was only 163 thousand hectares. The total production of all vegetables amounted to 5,278.9 thousand tons in 2021, and, despite the smaller cultivation area in 2022, it amounted to 5,387.0 thousand tons. The dominant crops are field vegetables which were cultivated on an area of 157.8 thousand hectares and their harvest amounted to 3.85 million tons. Vegetables under the shelter were grown last year on an area of 5,220 hectares, while the harvest is estimated at 1.53 million tons.

For many years, farms that operate in large-scale vegetable cultivation have been trying to develop the most effective long-term solutions that will allow them to gain a market advantage over the strong position of their competitors (Fałkowski, Chlebicka, 2021; Knook et al., 2022). It is estimated that the membership in cooperatives in the food industry in the EU countries is above 50%, depending on each individual country. Such forms and types of cooperation initiated by the European community may include farming cooperatives or various types of unions, associations or groups of agricultural producers. One of the barriers that affect farmers' association into groups is in their mentality – particularly a fear of losing independence as well as some administrative barriers. Joining a producer group is intended to reduce costs directly related to the use of industry machines or the group implementation of quality certificates. It is also important to reduce transaction costs, which involve saving time for negotiating the scope of sales. The statistical data included in Table 1 confirm the existence of few fruit and vegetable producer groups in Poland. Despite constantly increasing funding, a decline in the number of such groups can be seen in recent years.

Number of recognized producer organizations that manufacture fruit and vegetables in total, by Polish Provinces in 2017-2023

Province	Measurement period						
	06.2023	10.2022	10.2021	10.2022	10.2019	10.2018	10.2017
Dolnośląskie	6	6	6	6	8	8	8
Kujawsko-Pomorskie	14	14	18	23	29	33	38
Lubelskie	18	19	21	23	26	29	27
Lubuskie	1	1	1	3	5	5	4
Łódzkie	15	15	15	16	17	17	17
Małopolskie	8	8	10	11	12	11	11
Mazowieckie	56	58	61	74	82	84	84
Opolskie	5	5	5	5	5	5	5
Podkarpackie	3	3	3	5	6	6	6
Podlaskie	1	1	1	1	1	1	1
Pomorskie	4	4	4	6	7	7	7
Śląskie	3	3	3	3	3	3	3
Świętokrzyskie	10	10	11	11	12	14	14
Warmińsko - Mazurskie	1	1	1	2	2	2	2
Wielkopolskie	15	15	18	25	36	46	46
Zachodniopomorskie	1	1	1	1	1	1	0
Total	161	164	179	215	252	272	273

Source: Author's own study based on statistical data (ARMiR, 2023).

From the analysis based on data from the Central Statistical Office, it can be seen that the average monthly consumption of vegetables per a city resident in 2018 was 7.7 kg, while in the countryside it was 8.3 kg. Comparing fruit consumption respectively, it was 4 kg and 3.3 kg. In 2016, the corresponding amount of consumption of vegetables in the household was 8.59 kg, and fruit – 3.66 kg. Vegetable consumption in 2021 was 7.43 kg per month, while in 2004 this value was 12.3 kg (GUS - Local Data Bank, 2021).

The basic factor in vegetable production invariably remains the soil, regardless of technological progress. It is extremely important to adapt the possibilities of using soil to natural conditions and ensure that their use does not affect the environment adversely, while allowing for the economic development of the areas. According to the statistical data from the Central Statistical Office and the Agency for Restructuring and Modernization of Agriculture (ARMA), the average size of a farm in Poland is over 10 hectares (Table 2).

Table 2.

The average size of agricultural acreage a farm, by individual Provinces (hectares)

Province	2022	2021	2020	2019	2018	2017	2010
Dolnośląskie	18.00	17.79	17.29	17.1	16.72	16.46	15.72
Kujawsko-Pomorskie	17.01	16.83	16.58	16.43	16.14	15.77	15.01
Lubelskie	8.16	8.07	7.98	7.93	7.86	7.73	7.4
Lubuskie	23.03	22.75	22.29	21.9	21.52	21.18	20.32
Łódzkie	8.10	8.06	7.98	7.92	7.84	7.72	7.42
Małopolskie	4.28	4.22	4.16	4.13	4.1	4.04	3.83
Mazowieckie	8.90	8.85	8.77	8.75	8.68	8.57	8.44
Opolskie	19.66	19.50	19.16	19.02	18.69	18.51	17.83
Podkarpackie	5.10	5.03	4.94	4.9	4.83	4.77	4.47
Podlaskie	12.73	12.66	12.55	12.51	12.44	12.27	12.11

Cont. table 2.

Pomorskie	20.16	19.97	19.62	19.58	19.42	19.16	18.84
Śląskie	8.45	8.32	8.14	8.02	7.85	7.7	6.83
Świętokrzyskie	6.00	5.94	5.88	5.82	5.77	5.67	5.42
Warmińsko-Mazurskie	23.63	23.55	23.25	23.25	23.05	22.79	22.95
Wielkopolskie	14.41	14.27	14.09	13.99	13.74	13.56	13.43
Zachodniopomorskie	32.80	32.58	31.75	31.44	30.78	30.35	30.3
Average	11.32	11.20	11.04	10.95	10.81	10.65	10.23

Source: Author's own study based on data from the Central Statistical Office and ARMA (GUS - Statistical Yearbook of Agriculture, 2022; ARMiR, 2022).

In Poland, the area of vegetable cultivation in 2018 amounted to a total of 158.9 thousand hectares, which constitutes 1/6 of all crops sown. The most favourable vegetable production, considering the countrywide area of cultivation over 10 years, was recorded in Kujawsko-pomorskie and Dolnośląskie Provinces of Poland. However, many administrative units had a negative growth in the area of vegetable production, the smallest number of which included: Lubelskie, Podlaskie and Łódzkie Provinces (Table 3).

Table 3.

Sowing areas for field vegetables (in thousand hectares)

Province	2021	2020	2018	2015	2008
Dolnośląskie	9.1	9.8	12.1	8.6	9.6
Kujawsko-Pomorskie	25.7	29.7	30.4	24.5	17.5
Lubelskie	17.7	15.9	12.7	15.8	23.3
Lubuskie	4.2	4.9	4.8	4.5	5.2
Łódzkie	17.2	15.7	14.1	17.4	22.3
Małopolskie	15.3	14.5	14.1	17.5	17.4
Mazowieckie	20.2	21.1	23.4	25.6	28.1
Opolskie	2.4	2.1	2.8	3.3	2.8
Podkarpackie	4.6	3.7	3.5	4.8	8.4
Podlaskie	1.4	1.4	0.7	1.8	3.8
Pomorskie	7.1	8.1	8.9	7.3	8.8
Śląskie	1.7	1.7	1.8	2.6	3.7
Świętokrzyskie	10.8	10.6	9.6	13	15
Warmińsko-Mazurskie	7.5	7.1	3.5	3.1	3.5
Wielkopolskie	21.7	20.1	16	23.4	24.2
Zachodniopomorskie	3.1	3.9	3.3	2.9	4.2

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

Poland is a leader in vegetable production among other EU countries. As early as in 2017, the harvest reached significant volumes. In 2017, the total of over 4,583 thousand tons of field vegetables were collected in the country. In 2018, over 4,109 thousand tons were collected (on yearly average). Vegetables grown under the shelter constituted just over 1,161 thousand tons in 2018 (GUS - Production of agricultural and horticultural crops in 2018). Respectively, tomatoes under the shelter constituted a harvest of 675.8 thousand tons, cucumbers 293.3 thousand tons, other vegetables grown under the shelter accounted for 192.5 thousand tons. Among ground vegetables, the highest yield was from cabbage (913.2 thousand tons), which constituted almost 22% of all vegetables grown in the field. The second highest yield

were edible carrots (726.4 thousand tons), which accounted for almost 17% of the harvest of ground vegetables. Onion (562.9 thousand tons) took up over 13%.

In 2021, a total of over 3,803 thousand tons of field vegetables were harvested. The total production of vegetables grown under the shelter amounted to 1,220 thousand tons. Respectively, tomatoes under the shelter constituted a harvest of 655 thousand tons, cucumbers 305 thousand tons, other vegetables grown under the shelter accounted for 260 thousand tons. Among ground vegetables, the highest yield was from cabbage (687 thousand tons), edible carrots (637 thousand tons), and onions (617 thousand tons).

In the years 2017-2021, there was a decrease in yield from field vegetable crops. This resulted from the insufficient amount of water in the soil, which was partly due to global warming as well as less waste, and maintaining relatively unprofitable sales prices of vegetables compared to the production costs incurred. The yield of field cucumbers decreased by almost half, but the main reason for the decline in the harvest of vegetables grown in the field was the gradual reduction of the cultivated area (Table 4).

Table 4.

Harvest yield volume of selected vegetables in Poland in 2021-2017 (ground and grown under the shelter, in thousands of tons)

Item	Yield (thousand tons)					Cultivation area				
	2021	2020	2019	2018	2017	2021	2020	2019	2018	2017
Total vegetables	5023.0	4900.2	5019.0	5270.5	5704.8	152.9	151.3	181.8	183.8	183.6
Ground vegetables including:	3803.0	3868.3	3845.0	4109.0	4583.3	144.7	143.2	176.2	176.1	177.6
Cabbage	687.0	710.2	837.0	913.2	1010.5	13.7	13.6	20.8	20.7	20.5
Onion	617.0	660.4	535.5	563.0	667.4	22.8	24.8	24.	24.8	26.0
Edible carrot	637.0	671.3	678.3	726.4	827.1	17.6	17.4	22.2	22.4	22.1
Beetroots	239.0	261.0	281.0	298.2	336.4	7.1	7.2	10.4	10.2	10.0
Cucumbers	127.0	181.3	223.3	245.4	249.1	5.4	5.2	15.1	14.6	14.0
Tomatoes	158.0	186.0	240.5	253.0	254.5	6.2	6.0	10.0	9.7	9.3
Cauliflowers	138.0	150.0	207.0	219.9	238.3	5.4	5.1	9.4	9.3	9.1
Vegetables grown under the shelter including:	1220.0	1032.0	1170.0	1161.6	1121.5	8200.0	7114.5	5586.4	5670.0	5629.0
Tomato	655.0	555.0	677.3	675.8	643.5	3000.0	2560.5	2102.6	2141.0	2150.3
Cucumbers	305.0	267.3	297.1	293.3	294.6	1700.0	1451.0	1110.8	1115.4	1139.6
Other vegetables grown under the shelter	260.0	209.6	194.9	192.5	183.4	3500.0	3103.1	2373.0	2413.5	2339.0

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2017; GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2019; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

Over recent years, the purchase prices of vegetables, both for the fresh market and for food processing, have fluctuated significantly, depending on the yield and demand in a given season (Table 5).

Table 5.
Rates paid to producers for vegetables (PLN/kg)

Item	For the fresh produce market				For the needs of food processing industry			
	2018/19	2019/20	2020/21	2021/2022	2018/19	2019/20	2020/21	2021/2022
White cabbage	1.30	0.80	0.75	1.10	0.70	0.60	0.70	0.80
Onion	1.65	1.10	0.90	1.00	2.10*	1.50*	1.10*	1.40*
Carrot	1.50	0.85	0.70	1.10	0.35	0.30	0.30	0.35
Beetroot	0.80	0.70	0.65	0.90	0.45	0.40	0.40	0.45
Ground tomato	1.00	1.00	1.50	1.70	0.60**	0.70**	0.75**	0.75**
Ground cucumber	2.10	1.80	2.70	3.50	1.50***	1.60***	1.80***	2.20***

*peeled onion; **tomatoes for freezing; ***cucumbers for pickles.

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2019; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

According to the Central Statistical Office data, the average annual consumption of vegetables, mushrooms and their products per capita was 54.96 kg in 2020, and 57.84 kg in 2015 (Table 6).

Table 6.
Average annual consumption of vegetables in households (in kg/person)

Item	2020	2019	2018	2017	2016	2015
Vegetables, mushrooms and preserves	54.96	55.2	56.4	58.2	59.04	57.84
Fresh and chilled vegetables and mushrooms:	44.88	44.04	45.84	47.64	48.6	47.88
Cabbage	4.44	4.32	4.68	5.04	5.28	5.4
Onion	5.28	5.04	5.16	5.4	5.4	5.4
Edible carrots	5.16	4.92	5.28	6	5.88	5.64
Beetroots	1.92	1.92	2.16	2.4	2.52	2.4
Cucumbers	5.28	5.64	5.76	5.88	6.36	6.12
Tomatoes	9.6	9.48	9.72	9.6	9.96	10.08
Cauliflowers	1.8	1.8	1.8	1.8	1.8	2.04
Other vegetables	10.92	10.92	11.28	11.52	11.4	10.8
Frozen vegetables	2.16	2.04	1.92	1.92	1.92	1.8
Vegetable preserves	7.92	9.12	8.64	8.64	8.52	8.16

Source: Author's own study based on (GUS - Household budget survey in 2020; Statista, 2022).

In 2021, Polish exports of vegetables and vegetable products reached EUR 1.9 billion and were 7% higher than in 2020. Among fresh vegetables, mushrooms, tomatoes and onions were the most exported, and processed vegetables exports were dominated by frozen vegetables, potato products (chips and chips) and dried and preserved vegetables. The export of vegetables and vegetable products in 2021 accounted for 5% of the value of all Polish agricultural food exports. The largest recipients were the EU countries, and the revenues obtained amounted to EUR 1.3 billion, which constituted 70% of the value of total foreign sales of vegetables.

The largest EU recipients were Germany (EUR 415 million – 22% of this group's exports) and France and the Netherlands (EUR 118 million and EUR 103 million respectively – 6% each), and from outside the EU - Great Britain (EUR 226 million – 12%), the Russian Federation (EUR 78 million – 4%) and Ukraine (EUR 61 million – 3%).

The Institute of Agricultural Economics and Food Economy forecasts that, in the 2022/23 season, the export volume of fresh vegetables will be approximately 13% higher than in the previous season and will amount to 630-632 thousand tons (IERiGŻ, 2023). Exports of processed vegetables will increase from 722.3 to 746 thousand tons, including frozen vegetables – an increase from 432.3 to 445 thousand tons.

According to the data from the Central Statistical Office, there were 1.448 million agricultural tractors in Poland in 2020. Compared to 2010, this number increased by almost 30,000 units. (2005 – 1.437 million, 2010 – 1.418 million, 2013 – 1.436 million, 2016 – 1.492 million, 2020 – 1.448 million). The vast majority of machines operate on individual farms – in 2020 it was 1,430 million pieces. The average nominal power of the tractors used in Polish agriculture is systematically increasing and reached 46.9 kW in 2020 (2005 – 39.3 kW, 2010 – 37.9 kW, 2013 – 42.5 kW, 2016 – 45.3 kW, 2020 – 46.9 kW). In 2020, statistically, there was one tractor per 10.1 hectares of agriculturally usable land. The largest number of hectares per tractor is in Zachodniopomorskie Province (29.4 ha), Lubuskie Province (22.2 ha) and Warmińsko-mazurskie Province (18.9 ha). Currently, 66.9 % farms have an agricultural tractor in their machinery. As far as the farm size is concerned, the data is as follows: up to 1 ha - 31.5%, 1.01-1.99 ha - 35.6%, 2-4.99 ha - 58.7%, 5-9.99 ha - 80.7%, 10-14.99 ha - 89.3%, 15-19.99 ha - 91.3%, 20-49.99 ha - 91.4%, 50 ha - 89%.

The selected basic forms of market organization include: agricultural and horticultural trade centers, commodity exchanges, fairs, auctions and tenders. The construction of food wholesale markets in Poland was initiated by a ministerial program in July 1996. As a result of its implementation, 13 wholesale markets were created, with the largest one created on the outskirts of the capital - Warszawski Rolno-Spożywczy Rynek Hurtowy S.A. in Bronisze. Currently, there are 29 wholesale markets in Poland, including 5 cross-regional, 9 regional and 15 described as local. The wholesale markets take organizational and infrastructural measures to optimize trading conditions. These companies do not conduct commercial activities themselves, their basic activity being the rental of commercial space to operators - entrepreneurs and agricultural producers. The basic income of the wholesale markets are the revenues from the rental of commercial space and entry fees for buyers. There is certain infrastructure in the markets' premises - shopping halls, commercial and warehouse pavilions and shelters or stalls. The facilities are designed for year-round operation, some have the ability to adjust the temperature to optimal conditions for storing goods, which helps maintain the appropriate quality of the products offered. Some of the markets have some specialized infrastructure, such as ripening rooms, storage rooms, cold stores. The functioning of wholesale markets plays

an important role in the distribution of agricultural and food products. Despite growing competition from large-scale retail chains, the wholesale markets maintain their position on the market, primarily by offering high-quality, fresh goods. The total area of cross-regional, regional and local markets in Poland is presented in Table 7.

Table 7.

Selected cross-regional, regional and local markets in the country, including the area and location of a given market

Cross-regional markets		
Lubelski RH (Rynek Hurtowy) "Elizówka" SA	Lublin	47.3 ha
Warszawski Rolno-Spożywczy RH SA	Warszawa-Bronisze	42.5 ha
Wielkopolska Gildia Rolno-Ogrodnicza SA	Poznań	38 ha
Pomorskie Hurtowe Centrum Rolno-Spożywcze SA „Renk”	Gdańsk	24.7 ha
Dolnośląskie Centrum Hurtu Rolno-Spożywczego SA	Wrocław	37 ha
Regional markets		
Małopolski RH	Tarnów	18 ha
Podlaskie Centrum Rolno-Towarowe SA	Białystok	10 ha
Rolno-Spożywczy RH SA	Radom	6 ha (Radom) + 3 ha (Kielce)
Podkarpackie Centrum Hurtowe "Agrohurt" SA Rzeszów	Rzeszów	7 ha
Rolno-Spożywczy RH "Giełda Elbląska" SA	Elbląg	3 ha
Rolno-Przemysłowy RH "Giełda Hurtowa" SA	Legnica	No data
Małopolski Rynek Hurtowy SA Tarnów	Tarnów	18 ha
Wałbrzyski RH SA	Wałbrzych	4000 m ²
Zielonogórski Rynek Rolno-Towarowy SA	Zielona Góra	No data
Local markets		
Łódzki Rynek Hurtowy "Zjazdowa" SA	Łódź	14 ha
Gorzowski Rynek Hurtowy SA	Gorzów Wielkopolski	12.7 ha
Pilski Rynek Hurtowosp. z o.o.	Piła	3 ha
Beskidzki Hurt Towarowy SA	Bielsko Biała	11.3 ha
Praska Giełda Spożywcza SA	Ząbki	12 ha
Giełda Kaliska sp. z o.o	Kalisz	7.4 ha
Rynek Hurtowy Rolno-Spożywczy „Fasty” sp. z o.o.	Białystok - Fazy	5 ha
Sandomierski Ogrodniczy Rynek Hurtowy SA	Sandomierz	5 ha
Śląska Giełda Kwiatowa „Synergia” sp. z o.o.	Tychy	5 ha
Śląski Rynek Hurtowy „Obroki” sp. z o.o.	Katowice	10 ha
Świętokrzyski Rynek Hurtowy sp. z o.o.	Kielce	3 ha
Zachodniopomorskie Centrum Hurtowe „Rolhurt” SA	Przeclaw - Szczecin	3 ha
Targpiast sp. z o.o.	Wrocław	12.7 ha

Source: Author's own study based on data published by trading markets.

3. Case study

The object of the research was a family horticultural farm managed and run by a married couple. The surveyed farm is one of the leading producers of selected vegetables in the country. The manufacturer's wide offer is aimed at wholesale, industrial and retail markets, and willingly adapts to market trends. The analyzed farm is located in the county of Warsaw. The steady, consistent development of the farm is possible with EU support and investments that affect the

possibilities and improvement of production, as well as the efficiency of the appropriate use of resources in order to increase the profit and value of the activity.

The surveyed company has been allowed to deduct VAT (value-added tax) from purchases since 2006, which is why it pays taxes on general terms. Such a tax deduction makes it possible to recover part of the costs incurred, but the necessary condition for such a possibility is to submit a tax declaration to the Tax Office each month. The farm was additionally supported by subsidies from the "European Agricultural Fund for Rural Development, specifically Europe investing in rural areas". The farm was also included in the Rural Development program for 2014-2020. Given this extent of support, the business introduced some new investments, e.g. the construction of a cold storage facility.

The production farm is a large-scale vegetable cultivation operation, with a small percentage of cereal growing. The report which summarizes the yield volume on the farm for 2019 shows that the largest area on the farm is occupied by potato farming, with the annual yield of this vegetable of approximately 1,500 tons. The farm sells vegetables for 10-12 months of the year. The availability of the potato throughout the year is recorded from July 15 of the production year to March 15 of the following year. The onion is the second largest plant yield of about 700 tons, and the period of this vegetable's availability is from July 15 of a given year to April 30 of the following year. The next largest is the carrot yield of 400 tons and this vegetable is available from July 22 this year until April 30 of the next year. Apart from that, approximately 180 tons of Hokkaido pumpkin and common pumpkin were obtained in the period from September 15 this year. until April 30 of the next. All vegetables produced on the farm are sold on the domestic market.

The farm area is 35 hectares of own land, including 5 hectares of permanent meadows, which the farmer uses mainly for the disposal of natural waste, and 30 hectares leased from private individuals. The leased lands are located at a maximum distance of 10 km from the farm itself. The precise division of surveyed farm's area is presented in Table 8.

Table 8.

Farm area (in hectares)

Terrain type	Land owned [ha]	Land leased [ha]	Total
Arable land	30	30	60
Pastures	0	0	0
Permanent meadows	5	0	5
Agriculturally usable land in total	35	30	65

Source: Author's own study based on data received from the farm.

The farm has precisely assigned areas of land for a specific vegetable. The size of land allocated for the potato cultivation is 30 ha. The onions grow on an area of 20 ha, the carrots cover 7 ha, and both the Hokkaido pumpkin and the common pumpkin cover 3 ha. The total area of land under cultivation is 60 ha.

The yield of the carrot has the highest ratio of productivity efficiency on the surveyed farm. The second average yield size per hectare is for the onions, the third for the potatoes, and the last for the pumpkins. As with almost every production, a certain amount of waste is generated on the farm. Having been collected, the waste is transported to the field or meadow. The volume of production waste is respectively: pumpkins approx. 15%, carrots approx. 6-7%, onions approx. 7-10%, potatoes approx. 7-10%. A detailed list of yields is presented in Table 9.

Table 9.*Vegetable yield volume per hectare*

Vegetable	Yield size
Carrot	80-100 tons/ha
Onion	60 tons/ha
Potato	40-50 tons/ha
Pumpkin	28-45 tons/ha

Source: Author's own study based on data provided by the surveyed farm.

The farm is seasonal in its nature, which results in an increased demand for employees during periods of increased intensity of field work; during this period, 3 to 6 additional employees are hired on top of the 5 household residents who work full-time. Detailed data is presented in Table 10. The table calculates the average number of working hours of the household residents, depending on the average number of hours of total employees (data from 2019). Conversion factors and the sum of hours worked are presented in Table 10. The employment rates and man-hours were calculated on the surveyed farm.

Table 10.*Labour resources on the surveyed farm*

Household resident	Age (years)	Conversion factor for an able-bodied person	Number of hours worked on the farm (man hours/year)	Conversion factor for a full-time employee	Number of fully-employed and able-bodied people
1	2	3	4	$4/2200=5$	$5*3=6$
Owner	50	1.00	2940	1.34	1.34
Wife	50	1.00	1470	0.67	0.67
Father	70	1.00	1960	0.89	0.89
Mother	70	1.00	980	0.45	0.45
Cousin	60	1.00	2450	1.11	1.11
Total able-bodied people		5.00	-	-	-
Total number of hours worked on the farm			9800	-	-
Total number of full-time employees				4.45	-
Total number of full-time and able-bodied people					4.45

Source: Author's own study, data obtained from the farm.

Figure 1 shows the size of employment required on the surveyed farm in the years 2010-2019. The factor that determines and directly affects the described value is the purchase of new machines and equipment for vegetable processing. In 2010, a tractor was purchased for the farm, which largely replaced many human activities. In the following years, as part of its investment development, the farm also purchased machinery and equipment, e.g. a trailed field

sprayer, a conveyor belt, a vegetable washer, and a selection table. The implemented investments began to bring appropriate results. After a thorough analysis of the efficiency of machines and work efficiency of employees per man-hour, the farmer could reduce employment as human work was gradually being replaced by machines. The best investment of the farmer turned out to be the purchase of a tractor with high power and processing power, as well as a bagging machine – a machine that renders the preparation of the order faster and largely automated. This investment made it possible to reduce the previously required work of 5-6 employees on the conveyor belt and the washing machine by 2-3 people.

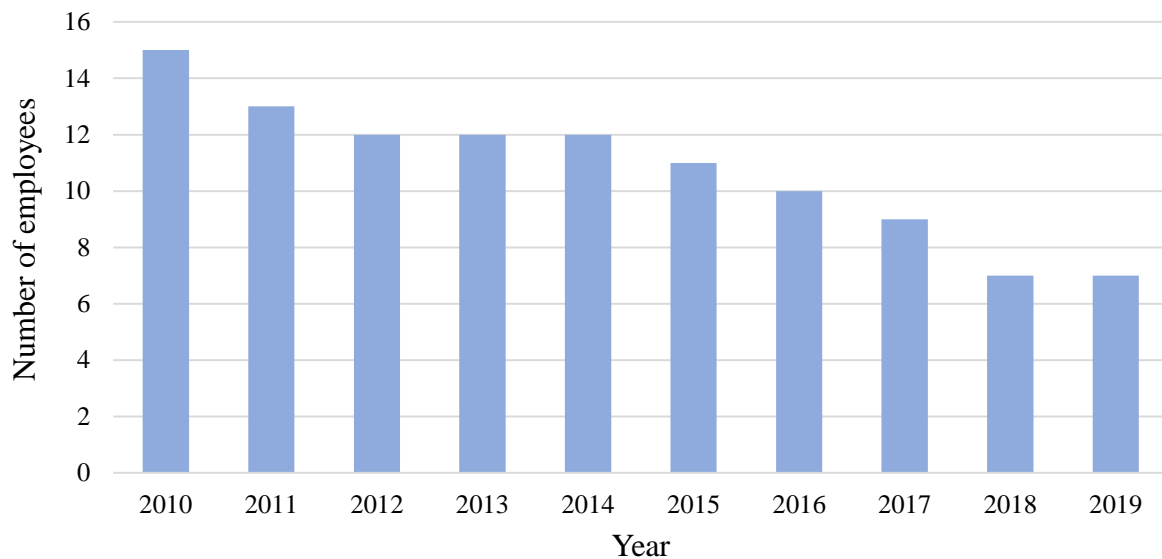


Figure 1. The impact on the size of employment through the purchase of machinery over 10 years
Source: Author's own study based on data obtained from the farm.

3.1. Equipment on the surveyed farm

The surveyed farm has 2 cold chambers cooled by refrigeration units, which can accommodate 600 tons and 800 tons of vegetables respectively, in addition to regular 2 storage rooms with a total capacity of 1200 tons. The farm is also equipped with a shelter adapted for drying pumpkins and onions. In the storage halls, the temperature ranges from 1 to 10°C, depending on the ambient air temperature and sunlight at a given time of the year. The storage rooms are filled with box-pallets in which pumpkins, onions and potatoes are stored. Cold stores maintain a constant temperature of 2 to 5°C, depending on demand, and mainly carrots are stored there. The company also has a social room, a sorting room where vegetables are prepared for sale, and a large garage where most of the mechanical equipment is kept.

The farm features innovative machines that occupy a permanent place on the company's property and machines that mainly operate in the farming of arable fields and transport. This significantly improves the pace and efficiency of work. The farm also has at its disposal a semi-trailer for a truck, equipped with a cooling unit regulate the temperature during the transport of vegetables as well as 1 truck tractor. Additionally, the farm uses 1 delivery van to

fulfil small orders or to transport small items. The surveyed company also has 2 forklifts as well as 5 agricultural tractors used in daily work on the plant crops. The last breakthrough modernization introduced by the company in recent years was the purchase of a bagging machine – one person is required to operate the machine, while 3-4 people are needed at the selection table. All vehicles that belong to the company, along with their characteristics, are listed in Table 11.

Table 11.
Vehicles in stock of the surveyed company

Vehicle name	Manufacturer	Model	Year of production	Power [HP]	Notes
Farming tractor	Deutzfahr	AgroPlus 87	2010	87	Wheelbase 1.5m
Forklift	LINDE	H45D	2001	-	Has tippers for box-pallets
Forklift	Toyota	6FGL18	1997	-	
Truck tractor	SCANIA	CF	2008	410	Trailer-compatible
Delivery van	Mercedes	Sprinter	2002	129	

Source: Author's own study based on data obtained from the farm.

The detailed range of the company's machines and devices, which are also a permanent asset of the company, is presented in table 12.

Table 12.
Machines and farming devices, including harvesting devices

Machine/device name	Manufacturer	Notes
Seedbed cultivator	KONGSKILDE	4-metre Vibro master; 4-metre germinator
Plough	KUHN MASTER 4T+1	5 furrow; reversible
Disc harrow	KONGSKILDE	8 m
Cultivator-conditioner	ATTILA MASCHINO GASPARRDO	4 m with pin protection
Ridge former	BASELIER	Ridge spacing 4x75; used for carrot production
Potato planter	GRIMME G34T	4-row
Potato hiller	GRIMME	passive
Fertilizer spreader	KUHN RAUCH AXIS	none
Trailed field sprayer	TOSELLI	21 m with an air sleeve; 2000l
Rain shower	IRRILAND COMFORT	90x500
Vegetable seeder	Stanhay Singularie 870	Pneumatic, vacuum
Seedling planter	Lauwers	none
Stubble cultivator	KONGSKILDE Delta	working with a mechanical seeder used for aftercrops
Carrot harvester	DeWulf P3K	
Potato harvester	Grimme SE 15060	Includes an onion harvesting attachment
Storeloader		
Trailer		4,5 t for box-pallets
Transport trailer	Metaltech DB 8000	8 pcs
Onion digger	RUHENBERG ZVR 1350 TWIN	
Chives cutter		

Source: Author's own study based on data obtained from the farm.

The surveyed farm offers the sale of goods that are subject to the washing process: carrots, potatoes, onions and pumpkins. The ordered goods are sold loose, i.e. in packages, packed in raschel bags weighing from 10 to 15 kilograms, or in dedicated plastic boxes, depending on the

chain. The farm maintains the following temperatures during transport: carrots at 1-8°C, onions and potatoes at 5-15°C, pumpkins at 5-20°C, and combined transports at 3-10°C.

Considering the directions of production, farm owners must invest in and fully use the efficiency of machines and devices that enable efficient packaging of vegetables, in order to be able to sell to retail chains. A detailed share of the machinery on the farm is presented in Table 13.

Table 13.

Machines and equipment for production without and with washing of plants

Machines used for wet line			Machines used for dry production		
Equipment name	Brand	Notes	Equipment name	Brand	Notes
Receiving hopper	BIJSMA Hercules 2000L		Stockpile picker		
Belt conveyor	Remprodex		Belt conveyor		
Vegetable washer	PROVEGGA	2.5 m	Box-pallet tipper		
Water settling tank	HAITH		Sorter	PROVEGA	
Vegetable brusher		3 m	Multi-container scale	ALLROUND	
Selection table (roller), own production			Bagging machine	ALLROUND	
Belt feeder					
Filler					

Source: Author's own study based on data obtained from the farm.

3.2. Fertilizing vegetables

The surveyed farm applies appropriate soil fertilization, which is carried out before or during sowing, and adequately uses spraying with plant protection agents appropriate for cultivation, in compliance with all standards and recommended doses as well as original chemical compounds with an efficient (certified), modernized sprayer. Fertilizers are used preventively and as emergency.

The first step when using fertilizers in vegetable cultivation is to determine the area of cultivated land in order to calculate how much fertilizer and water should be used. This depends on many factors, including: plant variety, assessment of the seedling before planting, determining what was sprayed, planting spacing, weather conditions, cultivation of the preceding vegetable, method of applying fertilizer (manual or mechanical) as well as the operator who must know well the composition and appropriate doses of fertilizer assigned to appropriate vegetables in the regulations. To finalize the correctness of fertilization, the operator/contractor must complete the appropriate crop card and provide the complete fertilization record in the card. On the surveyed farm, spraying is used depending on the vegetables grown. The specification of fertilization characteristics is presented in Table 14.

Table 14.*Reason for fertilization on the surveyed farm*

Vegetable name	Application for	Notes
Potato	weeds	Spraying done 3 times in the crop cycle; twice fertilized; 5 plant protection agents used
	potato blight	
	alternariosis	
Onion	herbicides	2 different fertilizers used; 8 different agents used; spraying done 6 times in the crop cycle
	grey mould	
	tobacco thrips	
	insects	
Carrot	herbicides	2 different fertilizers used; spraying done 4 times in the crop cycle; 4 different agents used
	alternariosis	
	mildew	
Hokkaido pumpkin	herbicides	spraying done with 2 different agents at the same time; spraying done once in the crop cycle

Source: Author's own study based on data obtained from the farm.

By regularly testing the concentrations of various chemical compounds in the soil as well as dosing fertilizers in accordance with specific standards, the farm contributes to the overall assessment of product quality. The selected family farm has had the GLOBALGAP certificate for its products since 2008. Additionally, the company has implemented the Hazard Analysis and Critical Control Points system (HACCP), a quality and food safety management system.

3.3. Sales volume and development prospects

The costs of running the surveyed farm are mainly incurred for current expenses related to the purchase of seed material, fertilizers, plant protection agents, fuel, energy consumption as well as lease fees and staff employment costs. The company incurs costs related to improving the standard of the facility, renovation works, e.g. expansion and modernization of warehouses and cold stores. In order to meet the expectations of the production of good quality vegetables, it is necessary to constantly invest in modern, more efficient machines for harvesting and packaging vegetables as well as replacing the machinery, namely tractors. Over the course of 3 years, the company has increased its revenue by approximately 30%, and the level of costs and investments has also increased significantly. Comparing the farm's financial data from the past three years, it turns out that the situation on the farm is very good as the revenues significantly exceed the costs. The company purchased machines such as: a tractor unit with a refrigerated trailer, a potato harvester, a sprayer, 2 agricultural tractors as well as smaller soil cultivation machines. Moreover, cold stores for vegetables were modernized by replacing refrigeration units. The analyzed costs result from purchase invoices and declarations submitted to ZUS (Social Security Office). The company's revenues are presented together with the incurred costs in Figure 2.

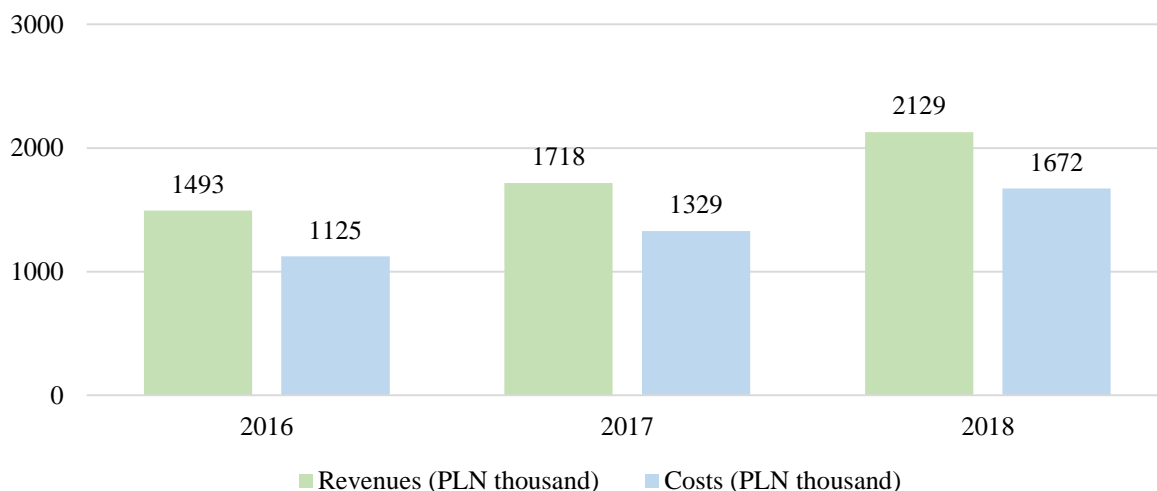


Figure 2. Revenues and costs of a selected vegetable farm in 2016-2018.

Source: Author's own study based on data obtained from the farm.

When analyzing the revenues from each month of the year for 3 years, it can be easily observed that the largest revenues were generated in the autumn and winter months: October, November, December. The smallest amounts are recorded in April, May and June, when small amounts of vegetables are sold. During the analyzed years, the highest level of profit was achieved in 2018 (Fig. 3).

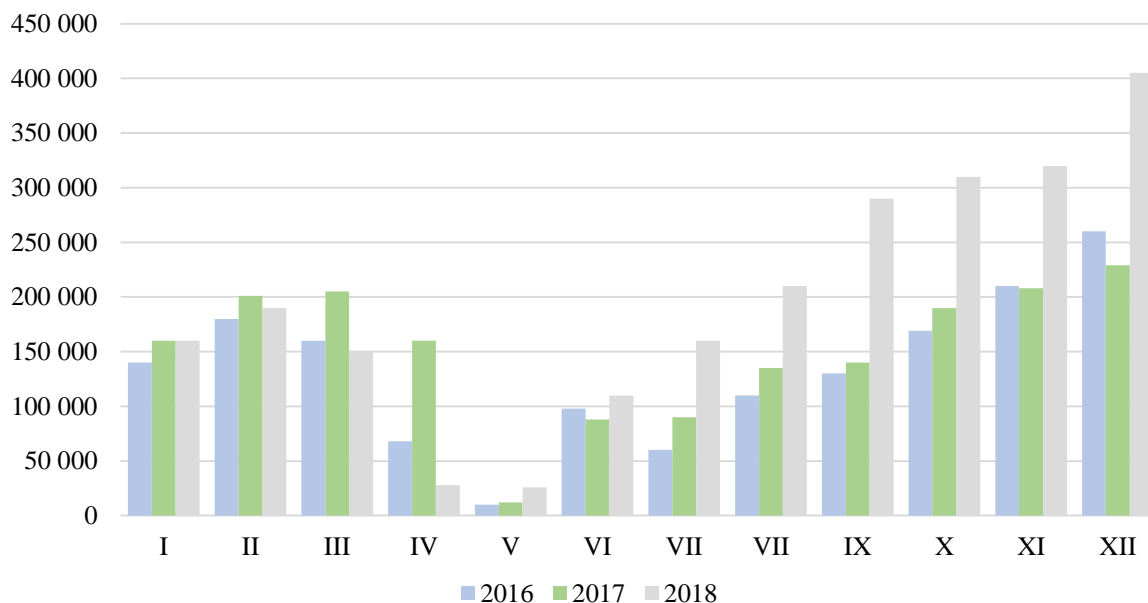


Figure 3. Revenues from the sale of vegetables by months and years 2016-2018 (in PLN).

Source: Author's own study based on data obtained from the farm.

The farm has been cooperating with a foreign hypermarket chain for 20 years. For 10 years it has also been supplying its products to a Polish supermarket chain. Such long-term cooperation has allowed the farmer to: double the cultivation area, invest in innovative machines and production lines, expand cold stores and storage rooms, introduce the GLOBALGAP system, participate in numerous training courses on the quality of agricultural

and food products, rodent control, HACCP, disinfection and pest control, Health and safety. The structure of vegetable sales on the surveyed farm is as follows: the hypermarket chain orders 60% of all crops, supermarkets purchase from 30 to 35%, and an intermediary production and trade company orders 5-10% of the harvest.

The farm delivers to the distribution centres of cooperating retail chains 5-6 times a week. The location of the farm favours cooperation with other trading units, as the distance of the farm from distribution centres is approximately 25-30 km, while the wholesale market is only 5 km away, and the intermediary company approximately 10 km.

While checking market prices and analyzing the profitability of selling vegetables at the selected farm to the above-mentioned distribution channels, the VAT invoices of the surveyed company were analyzed as well as the price reports of the Bronisze Wholesale Market. The selling prices of carrots to various customers were analyzed, which showed that it is best to sell to supermarket and hypermarket chains. Over the course of three years and 12 periods considered, the sales price of 1 kg of carrots was recorded 10 times as the highest in the case of distribution to hypermarket chains and supermarkets. The average sales prices of carrots to hypermarket chains were 14% higher, and to supermarkets by 6%, compared to the Bronisze Wholesale Market. The selling price of carrots to intermediaries was many times lower than the price quoted on the Bronisze Wholesale Market. A detailed breakdown of carrot sales prices and their prices in PLN per kilogram in 2016-2018 is shown in Figure 4.

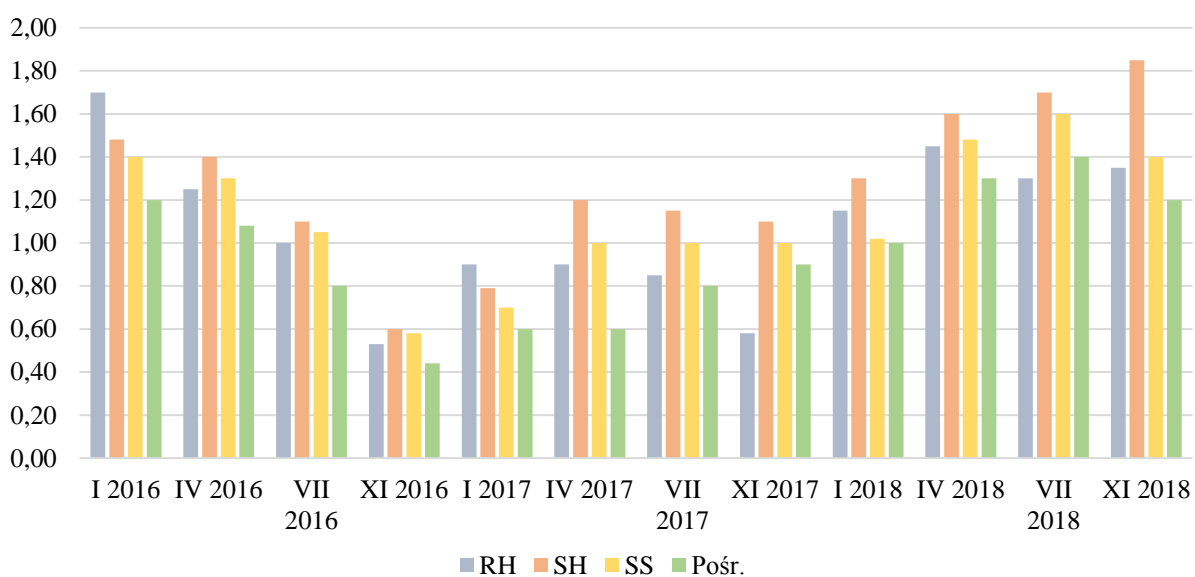


Figure 4. Sales prices to individual recipients (RH - wholesale market, SH - hypermarket chain, SS - supermarkets, Pośr. - intermediary) (in PLN).

Source: Author's own study based on data provided by the farm and data from the Warsaw-based agricultural and food company RH S.A. "Bronisze".

Potato sales also looked similar when analyzing sales offered to different recipients. In the same 12 analyzed periods as in the case of carrots, the price for 1 kilogram of potatoes was recorded as many as 9 times as the highest in the sale to supermarkets and hypermarket

chains. The average prices at these recipients were 8% higher than those at the Bronisze Wholesale Market.

Corresponding to the analyzed sales prices of carrots and potatoes, the sales price of 1 kilogram of onions was also the highest for supermarkets and hypermarkets, in 8 out of 12 examined periods. Prices were higher in the given chains than in the examined RH Bronisze by approximately 13%. Onion sales prices to intermediaries were on average 9% lower than in the examined Bronisze Wholesale Market.

Sales prices for various recipients were calculated by analyzing data provided by the farm and the Warsaw agricultural and food wholesale market RH S.A. "Bronisze". By examining the sales prices of selected vegetables listed earlier by individual recipients, it can be determined that, on average, the prices of retail chains are much higher compared to those at RH Bronisze, as well as those of the intermediaries. However, when market prices are very high, chains cannot pay such prices to the manufacturer. The middleman had the worst position because he bought vegetables at the lowest prices. The study did not take into account the costs of fuel, packaging or production of the goods.

On the farm under study, an annual increase in investment opportunities can be observed, and the company has ensured the high quality of the manufactured product over the years. The farm takes care of recycling and returns all plastic packaging. However, the farmer did not decide to introduce water reuse using a private sewage treatment plant on the farm, due to unprofitability.

4. Summary and discussion

The subject of the analysis was the technological and market aspects of vegetable production on the example of a selected farm. The article analyzed data on the condition of vegetable and agricultural farms in Poland. The production potential was presented as well as some differences in the volume of vegetable production. The paper presents changes taking place in the country over the years in the volume of vegetable yield. Lastly, the volumes of vegetable sales abroad and their purchase from other countries are presented.

The case study farm produces goods for over 10 months a year, which significantly affects the continuity of supplying the customer with fresh vegetables. The main recipients of its products are supermarket chains. Producing large quantities of goods requires adequate supply of warehouse space and vegetable processing halls. The surveyed farm is highly automated, innovative machines are a necessary annual investment of the farm in order to maintain its competitiveness and increase the value of the business. The farmer's activities were usually more intense in summer and autumn. An important factor in achieving success was the appropriate dosage and fertilization of the plants. One of the most important indirect factors in

the production of vegetables in the analyzed case is ensuring the appropriate quality of the product. The quality measured in the guidelines obtained by the farm for certificates as well as compliance with EU standards. The surveyed farm records a steady increase in investment opportunities as well as the improvement and introduction of recycling and ecological activities.

Managing a vegetable farm in an innovative way, considering the constant development of the business, is very demanding, labour-intensive and requires adequate capital. It is necessary to invest in new technologies, machines and devices that improve production and packaging, as well as to introduce possible changes that may bring an advantage over the competition in the long run. With a significant supply of vegetables on the market in the country, efforts should be made to improve efficiency, to conduct intensive production to reduce unit costs as well as to improve the yield per hectare. Nowadays, customers of vegetable farms pay particularly close attention to all aspects of plant production. Among other things, the type and quality of storage, compliance with many safety rules and the certificates held, which are necessary to be able to sell vegetables and fruits to retail chains.

Currently, the production market is extremely competitive. The number of regulations and the necessity to introduce system and management innovations are constantly growing. Thanks to the maximum use of technological resources available on farms that produce vegetables, producers are able to obtain yields many times higher than before. An important aspect of European farms in the coming years is the introduction of organic and safe food.

The sale of vegetables, with particular emphasis on the domestic market, depends mainly on supply. However, the supply is determined by weather conditions in the country, which affect the growing season and the quality of products. A high supply rate means that vegetable prices will be relatively low in comparison to the years in which supply was low. Farmers who cultivate large farms cooperate most profitably with retail chains. However, small producers should choose the wholesale market as their main supply channel if it is territorially convenient to supply the product to trade.

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