ECONOMIC EFFECTS OF INVESTMENT IN MINI DIGITAL SOLAR DRYER

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Abstract: *In theory and practice, there comes to increase in focus to digitalization in agriculture, as well as about the rational use of available natural resources, primarily land, water and energy. The use of renewables, such is solar energy, can be done in various purposes, for example for energy supply of, among other income-generating activities, processing capacities at the farms. However, agriculture in Serbia is still largely performed in traditional way, without implementation of innovative solutions, or use of modern knowledge. Caused by that, the main goal of this research is to determine the economic effects of investing in establishment of mini digital dryer based on solar energy, which can be used for drying fruits, vegetables, medicinal herbs, spices and mushrooms. Research is based on real data obtained from the use of digital solar dryer implemented at experimental farm, while for investment analysis are applied usually used dynamic methods. Analysis has also considered assessing the impact of change in investment, value of inputs (plant based raw material), or price of final food products on the gained results of economic analysis. The analysis has indicated positive economic results of introduction of innovative drying system for agricultural products, whereby the economic effects of investment are sensitive the most to change in price of final food products.*

Keywords: *investment, food processing, agricultural products drying, renewables, solar energy.*

JEL Classification: A10, C83

INTRODUCTION

Other gainful activities (OGA) performed on the farms (including processing of agricultural products) are receiving more and more attention in the business analysis of farms (McNally, 2002; Cholewa, Smolik, 2021). They provide the opportunity to better use the available capacities and gained primary products, to create additional income on the farm, i.e. to obtain value-added through the processing of agricultural products (Romagnoli et al., 2021; Shahzad, Fischer, 2022). Therefore, since 2014, the value of OGA has been monitored in the EU's FADN database (Graph 1.). Value of the total OGA output (SE700), as well as the value of total output (SE131) for the average EU's farm has growing trend, while the share of SE700 in SE131 is relatively stable, ranging between 5.18-5.66% in the observed period.

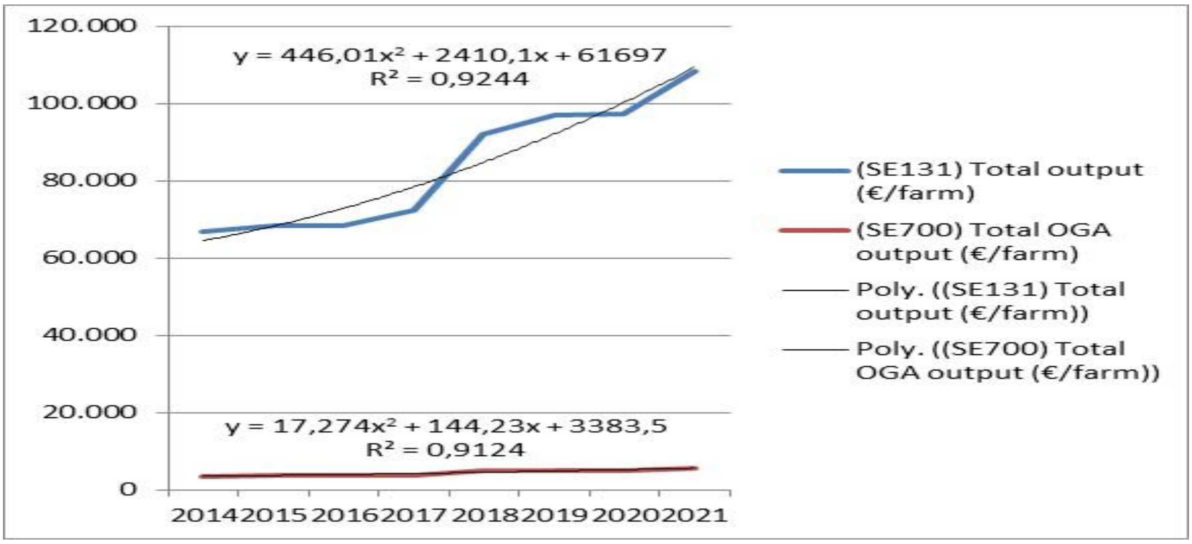

Figure 1. Value and trend of the SE131 and SE700

Source: Authors' calculation based on FADN, 2023

Special focus should be directed to activities linked to the processing of agricultural products, which are combined with strivings to increase global energy efficiency, i.e. that include the use of renewable energy sources (RES).

Several authors have been dealt in Serbia with the issue of the RES use in agriculture (Brkić et al., 2003; Tešić et al., 2006; Subić et al., 2017; Vasiljević et al., 2018; Gajdobranski et al., 2021; Jeločnik, Subić, 2021; Despotović et al., 2022), or specifically with the solar energy use in drying of fruits, vegetables, medicinal herbs and spices, and mushrooms (Doder, Đaković, 2017; Tasić et al., 2018; Nikolić, 2022).

Toward the Farm Structure Survey (FSS) for Serbia in 2018. (SORS, 2019), in overall number of farms involved in processing, there are over 45% of them active in milk processing, or 38% in fruits and vegetables processing. Besides, 8% of them are active in processing of other agricultural products, or 9% in meat processing (figure 2.).

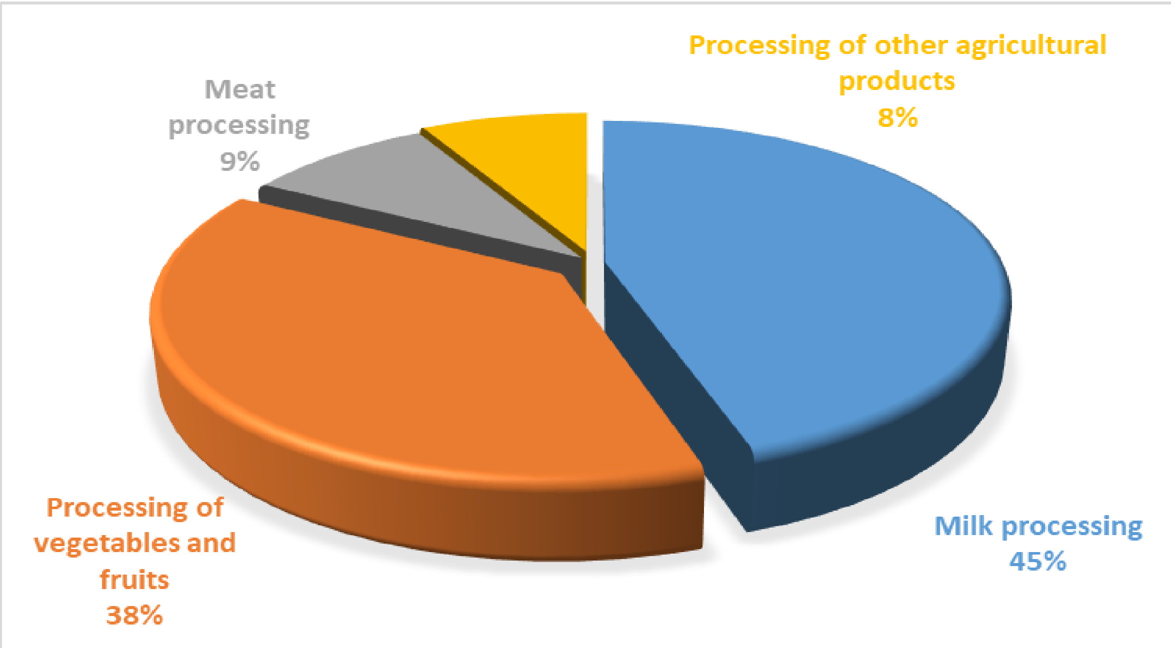

Figure 2. Structure of farms involved in agricultural products processing in Serbia (in %)
Source: SORS, 2019.

The use of fossil fuels in the process of artificial mechanical drying is expensive and certainly does not have a positive influence on environment and climate. Meanwhile, drying under the influence of solar heat and radiation is completely dependent on available weather conditions (Mustayen et al., 2014; Nukulwar, Tungikar, 2021).

Besides, drying of agricultural products directly by sun on open field is not suitable for large-scale production, as products are exposed to many external risks and damages (e.g. pests and microorganisms, rain, or dust), while the method is labor intensive and time consumed (Tiwari, 2016).

On the other hand, using solar dryers (drying system in a closed space) represents cheaper and more efficient method compared to drying products in open field (Mustayen et al., 2014). A study of Nukulwar and Tungikar (2021) shows that a solar dryer not only saves the fossil fuels, eliminating the negative impact of drying to environment, but also improve the hygiene and quality of dried products, especially in terms of taste and colors.

Some authors Fudholi et al. (2010) believe that the drying of agricultural and marine products represents one of the most attractive and profitable utilization of solar energy in the global business. Solar drying is becoming an increasingly popular alternative for replacing the mechanical dryers, both due to high energy prices and growing environmental awareness of agricultural producers and final consumers over the world (Asnaz, Dolcek, 2021).

In developing countries, food drying by the use of solar energy is increasingly emphasized as a way to effectively respond to demand for healthy, natural and cheap food products, while in same time provides sustainable income for farmers (Kumar et al., 2016; Udomkun et al., 2020).

The development of efficient and cost-effective solar dryer that includes a thermal energy storage system for permanent drying of agri-food products in stable manner and moderate temperatures (40-75°C) also imposes potentially viable alternative for fossil fuels in many developing countries (Bal et al., 2010).

Besides air-based solar collectors, there are also in use the water-based solar collectors, or their hybrids (Fudholi et al., 2010; Fudholi, Sopian, 2019).

The most dominant parameters that affect drying intensity in indirect type of solar dryers are: temperature and air flow speed, solar radiation, type of agro-product, initial content of moisture and overall mass of agro-product. The drying rate of processed food products within mentioned dryers was high, while the products' quality remained unchanged after drying (Lingayat et al., 2020).

In case of analysis of solar dryer and onions, Bennamoun and Belhamri (2003) have been indicated that the drying results are influenced by the overall surface of collector, air temperature, or characteristics of processed agricultural products.

Processor is mainly focused to costs optimization, achieving the energy efficiency, or final products' quality and price, while the greater use of dryer (out of season) will further decrease the costs of drying, ensuring the profitability of utilized investment (Tiwari, 2016).

The main goal of this research is to justify the investment in mini digital solar dryer, as well as to define which factors affects the investment profitability the most.

MATERIAL AND METHODS

An innovative facility for ecological processing, i.e. natural drying of fruits, vegetables, medicinal herbs, spices and mushrooms based on use of solar thermal energy transferred into the forced air flow was established on the experimental farm of the Secondary Agricultural-Chemistry School in Grabovac, Obrenovac municipality during the agricultural season 2022/23. As the research impose economic analysis of investment in innovative system for drying plant food products that originate from farm production, used data refers to those collected at the School's experimental farm. Besides, there are also used data from local markets, or several literary sources (professional and scientific literature) focused to processing of agricultural crops, or investments.

In order to monitor the trends of certain FADN indicators, such are total output and total OGA output, there is used the trend method. Assessing the economic effects of investment in innovative solar dryer, as in some previous research linked to the RES utilization, involve dynamic methods, i.e. net present value NPV, internal rate of return IRR, modified internal rate of return MIRR and dynamic payback period DPBP (Subić, Jeločnik, 2017; Subić, Jeločnik, 2016; Subić, Jeločnik, 2021; Jeločnik et al., 2016). In addition, it was analyzed the impact of change in size of investment, or value of costs of fresh crops (raw material), or price of food products (dried products), i.e. it was performed the sensitivity analysis of economic effects of investment (change in value of NPV, IRR, DPBP).

RESULTS AND DISCUSSION

In food industry, or food processing technology, one of the ways for natural preservation of food products represents the process of drying (dehydration), (Sagar, Suresh Kumar, 2010). The drying process requires the use of large volume of heat (for drying) and electricity (for airing), whether electricity is further converted into thermal energy, or some other energy sources such are natural gas, wood or biomass are initially combusted and later used for drying (Dev, Raghavan, 2012).

Energy costs significantly affect the price of final food products and overall profitability of production (Ciaian, 2011). On the other side, the sun represents infinite and totally free source of clean, or "green" energy (Sen, 2004), where solar thermal energy is used, which is contained in infra-red spectrum of solar radiation (mainly in range of 0.7 µm - 3 µm), (Granqvist, Niklasson, 2018). So, in research are determined the economic effects of the processing plant for ecologically sustainable use of solar energy for drying different types of products mainly in food industry, or potentially in wood industry.

The overall investment implies the value of 2,453,000.00 RSD (Table 1.), (1 EUR = 117.5 RSD). Within the structure of investment in fixed assets, the largest share has the investment in equipment, contrary to investment in implementation activities and facility. Investment is financed exclusively by own assets, without any credit lines from commercial bank.

Table 1. Overall investment in solar dryer (in RSD)

No.	Element	New investment	Total investment	Share in total investment (%)
I	**Fixed assets**	**2.230.000,00**	**2.230.000,00**	**90,91**
1.	Facilities	576.000,00	576.000,00	23,48
2.	Equipment	864.000,00	864.000,00	35,22
3.	Implementation	790.000,00	790.000,00	32,21
II	**PWC**	**223.000,00**	**223.000,00**	**9,09**
Total (I+II)		**2.453.000,00**	**2.453.000,00**	**100,00**

Source: IMP, IAE, 2023

General assumption in line to agro-economic analysis of investing in solar dryer is that working season of dryer (use of full capacity) is over the period May - October (180 working days), which largely overlaps with the fruiting season of crops that are usually subject to drying. This period characterizes maximal insolation, i.e. volume of solar energy that will be transformed into thermal energy required for drying the selected crops.

Practicing certain lines of agricultural production in larger scale on experimental farm and good marketability of dried food products have resulted in drying of primarily fruits and vegetables, such are plums (pitted), apples (rings without seeds), grapes (without seeds), peppers (whole fruit) and tomatoes (rings). Fresh vegetables are mainly produced in greenhouse, while fruits and grapes are grown in filed, ensuring good employment of dryer capacity in pre-defined working season. The basic expectations consider that selling of food products with higher degree of processing will activate created value added what will significantly affect the overall profitability of experimental farm. Analysis fits to production cycles of fruit, vegetable and grape growing during the season 2022/23.

Estimated value of fresh agro-products that enter the drying process represents their production costs per unit gained at the experimental farm. Used raw material, i.e. fruits, grapes and vegetables are classified as II class, having no mechanical damages, and satisfactory quality and nutritional value. So, fruits are classified only according to size and shape. Final food-products (dried fruits, grapes and vegetables) are sold at farm gate in bulk to local consumers, at sales prices slightly higher than usual, according to their eco-character based on performed eco-friendly drying process (Table 2).

Table 2. Forming of total income by the use of solar dryer (in RSD)

No.	Sales income	UM	Annual average		
			Price per UM	Annual quantity in UM	Total
0	1	2	3	4	5=3x4
1.	Dried pepper	kg	385,00	210,00	80.850,00
2.	Dried tomatoes	kg	860,00	270,00	232.200,00
3.	Dried apples	kg	905,00	315,00	285.075,00
4.	Dried plums	kg	415,00	550,00	228.250,00
5.	Dried grapes	kg	265,00	375,00	99.375,00
6.	Generated surplus of energy	KW	22,75	7.200,00	163.800,00
Total					**1.089.550,00**

Source: IMP, IAE, 2023

In some months, out of drying season, but with generally satisfactory insolation (March, April and November), it is estimated that the installed system for thermal energy generation can effectively work full two months. As at that time there are no drying activities, generated energy (7,200 KW) would be used for additional heating of production space at the experimental farm (barn and greenhouse), what will represent additional income for the school derived from the use of solar dryer system (savings in unspent electricity, i.e. costs cut for electricity for industrial users usually classified in high tariff).

Table 3. Total costs (in RSD)

No.	Class of costs	Years				
		I	II	III	IV	V
I	**Material costs**	**304.200,00**	**304.200,00**	**304.200,00**	**304.200,00**	**304.200,00**
1.	Direct material	272.500,00	272.500,00	272.500,00	272.500,00	272.500,00
2.	Energy	0,00	0,00	0,00	0,00	0,00
3.	Other material costs	31.700,00	31.700,00	31.700,00	31.700,00	31.700,00
II	**Non-material costs**	**468.458,33**	**468.458,33**	**468.458,33**	**468.458,33**	**468.458,33**
1.	Depreciation	100.458,33	100.458,33	100.458,33	100.458,33	100.458,33
2.	Labor	360.000,00	360.000,00	360.000,00	360.000,00	360.000,00
3.	Interest	0,00	0,00	0,00	0,00	0,00
4.	Other non-material costs	8.000,00	8.000,00	8.000,00	8.000,00	8.000,00
Total (I+II)		**772.658,33**	**772.658,33**	**772.658,33**	**772.658,33**	**772.658,33**

Source: IMP, IAE, 2023

The energetic sustainability of investment (solar dryers) does not require the use of electricity from the public grid during its exploitation (energy is drawn from solar energy). Of course, the possibility of access to the power grid is possible during longer period without solar insolation, in order to prevent a temporary stoppage of the food processing and negative impact on planned profitability.

Exploitation of dryer does not require special maintenance, except one-time disinfection after each individual drying cycle. In Table 3. are presented summary of all costs derived from processing of selected fruits, grapes and vegetables over the one season.

Profit-loss statement of analyzed investment is presented in next table (Table 4.).

Table 4. Profit-loss statement (in RSD)

No.	Element	Years				
		I	II	III	IV	V
I	**Total revenues**	**1.089.550,0**	**1.089.550,0**	**1.089.550,0**	**1.089.550,0**	**1.089.550,0**
1.	Sale incomes	925.750,00	925.750,00	925.750,00	925.750,00	925.750,00
2.	Generated surplus of electricity	163.800,00	163.800,00	163.800,00	163.800,00	163.800,00
II	**Total expenditures**	**772.658,33**	**772.658,33**	**772.658,33**	**772.658,33**	**772.658,33**
1.	Business expenditures	772.658,33	772.658,33	772.658,33	772.658,33	772.658,33
1.1.	Material costs	304.200,00	304.200,00	304.200,00	304.200,00	304.200,00
1.2.	Non-material costs without depreciation and interest	368.000,00	368.000,00	368.000,00	368.000,00	368.000,00

No.	Element	Years				
		I	II	III	IV	V
1.3.	Depreciation	100.458,33	100.458,33	100.458,33	100.458,33	100.458,33
2.	Financial expenditures	0,00	0,00	0,00	0,00	0,00
2.1.	Interest	0,00	0,00	0,00	0,00	0,00
III	**Gross profit (I-II)**	**316.891,67**	**316.891,67**	**316.891,67**	**316.891,67**	**316.891,67**
IV	**Tax on gross profit***	31.689,17	31.689,17	31.689,17	31.689,17	31.689,17
V	**Net profit (III-IV)**	**285.202,50**	**285.202,50**	**285.202,50**	**285.202,50**	**285.202,50**

* Rate of Tax on gross profit is 10%. Source: Calculated according to IMP, IAE, 2023.

Related to derived Cash flow investment is liquid during the overall observed period of investment exploitation, while the elements Economic flow are presented in Table 5.

Table 5. Economic flow (in RSD)

No	Element	Zero moment	Year				
			I	II	III	IV	V
I	**Total revenues (1+2)**	**0,0**	**1.089.550,0**	**1.089.550,0**	**1.089.550,0**	**1.089.550,0**	**2.668.591,7**
1.	Total incomes	0,0	1.089.550,0	1.089.550,0	1.089.550,0	1.089.550,0	1.089.550,0
2.	Salvage value	0,0	0,0	0,0	0,0	0,0	1.579.041,7
	2.1. Fixed assets	0,0					1.356.041,7
	2.2. PWC	0,0					223.000,0
II	**Total expenditures (3+4+5)**	**2.453.000,0**	**703.889,2**	**703.889,2**	**703.889,2**	**703.889,2**	**703.889,2**
3.	Investment	2.453.000,0					
	3.1. In fixed assets	2.230.000,0					
	3.2. In PWC	223.000,0					
4.	Costs without depreciation and interest	0,0	672.200,0	672.200,0	672.200,0	672.200,0	672.200,0
5.	Tax on gross profit	0,0	31.689,2	31.689,2	31.689,2	31.689,2	31.689,2
III	**Net profit (I-II)**	**-2.453.000,0**	**385.660,8**	**385.660,8**	**385.660,8**	**385.660,8**	**1.964.702,5**

Source: Calculated according to IMP, IAE, 2023

Reconsidering obtained results, it is expected that the experimental farm will achieve in next five years an NPV in value of 453,930.04 RSD (with assumed discount rate of 5%) by the exploitation of investment (solar dryer), (Table 6).

In accordance with the value of IRR investment could be considered economically justified, as its value is higher than assumed discount rate (9.87% > 5%).

The investment is also justified by indicator of MIRR method (8.63%). It is expected that the investment will be paid off in 4.71 years, what is a shorter than the usual credit line expiration (5 years), or exploitation period (above 20 years), so according to mentioned indicator investment could be also considered economically justified.

Table 6. Indicators of investment economic justification

Indicator	Value
Net Present Value	453.930,04 RSD
Internal Rate of Return	9.87%
MIRR	8.63%
Dynamic Payback Period	4.71 years

Source: Calculated according to IMP, IAE, 2023

In order to determine the impact of changing the most important factors on the economic effects of investment, sensitive analysis was performed. As analyzed component was occurred the increase in value of investment, assuming that the other parameters remain unchanged (Table 7.).

Table 7. Sensitivity analysis related to change (increase) in investment value

Change in investment value (in %)	Net Present Value	Internal Rate of Return	Dynamic Payback Period
+ 5%	340.016,36	8,52%	4,78 years
+ 10%	226.102,68	7,26%	4,85 years
+ 15%	112.188,99	6,08%	4,93 years
+ 20%	Negative	Lower than discount rate*	Over 5 years

Source: Calculated according to IMP, IAE, 2023. * Used Discount rate is 5%.

By sensitivity analysis was determined that in the case of increase in investment for 19.92% it will be achieved the threshold value, as in that moment NPV equalizes to zero.

In addition, it was done the impact analysis of the change (decrease) in price of final food products on economic effects of investment (Table 8.), assuming other parameters unchanged. In this case, the threshold value of NPV is achieved when the price of dried (final) food products is decreased for 12.58%, as then the NPV equals to zero.

Table 8. Impact of change in selling price of dried food products

Decrease in selling price of dried food products (in %)	Net Present Value	Internal Rate of Return	Dynamic Payback Period
- 5%	273.569,46	7,94%	4,82
- 10%	93.208,87	6,01%	4,94
- 15%	Negative	Lower than discount rate*	Over 5 years

Source: Calculated according to IMP, IAE, 2023. * Used Discount rate is 5%.

On the other side, increasing the price of inputs, i.e. raw material (Table 9.), such are fresh peppers, tomatoes, apples, plums and grapes (crops used in drying process) for 42.75%, the NPV equals to zero.

Table 9. Impact of change in price of fresh fruits and vegetables (costs of raw material)

Increase in price of input (in %)	Net Present Value	Internal Rate of Return	Dynamic Payback Period
+ 5%	400.839,84	9,30%	4,74
+ 10%	347.749,63	8,74%	4,77
+ 15%	294.659,42	8,17%	4,80
+ 20%	241.569,21	7,60%	4,84
+ 25%	188.479,01	7,03%	4,87
+ 30%	135.388,80	6,46%	4,91
+ 35%	82.298,59	5,89%	4,94
+ 40%	29.208,38	5,32%	4,98
+ 45%	Negative	Lower than discount rate*	Over 5 years

Source: Calculated according to IMP, IAE, 2023.

Gained results indicate that the NPV of observed investment is the most sensitive to changes in sales prices of dried food products, while it is somewhat less sensitive to the increase in overall investment, or the lowest impact on investment has the increase in inputs' (raw material) price.

As the level of NPV is the most sensitive to change in price of dried (final) products and amount of initial investment, there are also observed the combined impact of change in these two components on the level of NPV (figure 3.). So, it was analyzed the level of NPV for decrease or increase in value of both components by 5%, 10% or 15%.

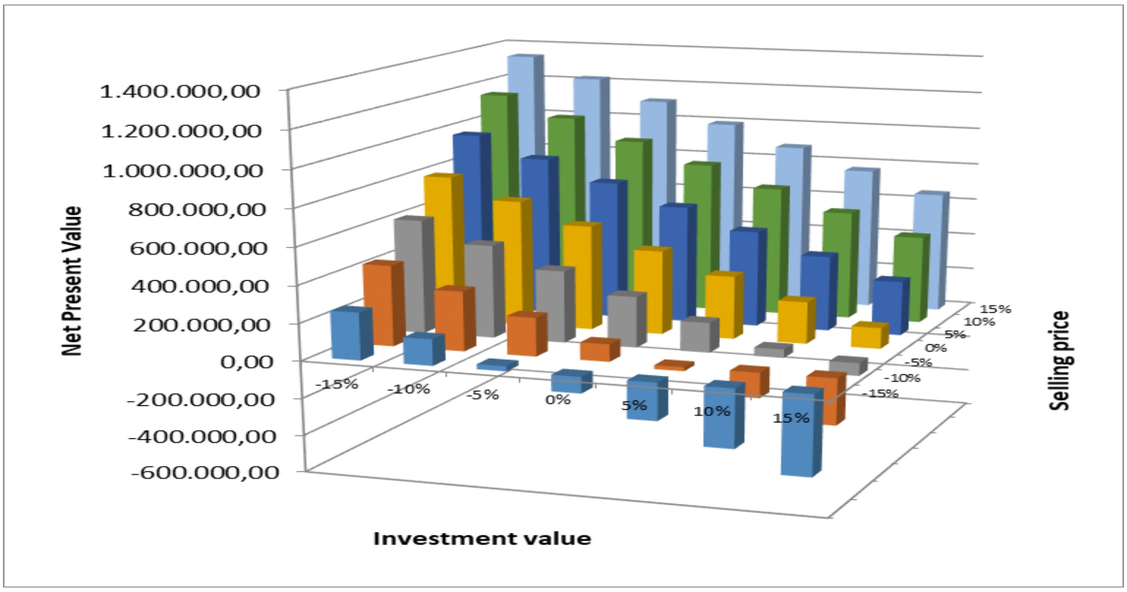

Figure 3. Combined impact of change in initial investment and price of final food products on the level of NPV (in RSD and %)

Source: Calculated according to IMP, IAE, 2023.

Gained results have been showed that just in few combinations of these two factors there comes to the negative NPV.

CONCLUSION

In paper is pointed out the positive trend of the value of total OGA output in EU, which also includes the processing of agricultural products at the farm level. It was also indicated that fruit and vegetable processing on the farm is the second most important agro - food processing segment in Serbia, right after the milk processing. The positive effects of investing in mini digital solar dryer (according to all indicators of the dynamic methods of investment assessment) indicate the justification and importance of implementing the modern systems in agricultural production that are based on the use of renewable energy sources. Besides the investment in solar dryer is being economically justified, in same time it is also liquid. The risk analysis showed that investors must primarily pay attention to achieving acceptable level of selling prices of final food products, as they have the greatest impact on the economic effects of investing. In other words, current state at the food market (including organic products), purchasing power and customer preferences, as well as their awareness regarding the importance of RES use in food production are among key elements for success within the analyzed business activity.

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