MANAGING THE PRODUCTION PROCESSES - OPTIMIZATION OF THE TECHNOLOGICAL PROCESS OF BANANA RIPENING BY APPLYING THE SIMPLE ADDITIVE WEIGHTING METHOD

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ABSTRACT

The realization of company goals is greatly influenced by the manager's decisions in the activities of managing production processes. To make decisions, managers use different decision-making methods, taking into account different criteria on the basis of which they choose the best alternative. The paper presents the optimization of the technological process of banana ripening using the simple additive weighting (SAW) method. The research monitored temperature correction, ripening gas dosage concentration, duration of treatment, commodity loss, including correction of accompanying factors of green banana fruit ripening. By applying the SAW method on 400 performed ripenings in the period from 2017 to 2020, the best results were achieved at a temperature of 18.5 °C, with an ethylene concentration of 840 ppm, process time of 112 h and achieved kalo of 233 kg. The total cost of ripening based on the examined parameters is 250.12 € which can save 81.42 € and meet the finishing standards.

Introduction

The management in the company strives for the realization business with minimal consumption of resources and achieving the highest possible quality of products and services with maximum profit. Due to the above mentioned, managers are faced with a large number of challenges (risks, uncertainties) and decisions that need to be implemented in order to achieve the best possible business results.

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Better efficiency and effectiveness in business provide the company with greater competitiveness in the market, and this is achieved by a continuous effort to match costs in reproduction and minimize investment of resources, thus obtaining maximum results. However, due to the complexity of production, including the effect of external and internal factors, there are often deviations in reproduction that incur additional costs.

In order to achieve efficiency and maximize profits in the company, costs need to be managed in all segments during the business engagement. The costs first need to be located and formulated and appropriate analyzes should be conducted in order to have them adequately planned and implemented. Production costs are influenced by a large number of factors (purchase price of means, costs of production elements, transport costs, etc.). The greatest significance and deviations in this segment are caused by the costs of means and reproduction itself, consumption of elements (materials) of production that enter the process of creating certain goods, costs of realization and services, labor costs (Coase, 2005; Stanciu et al., 2019; Stoica et al., 2022).

In order to meet the needs of the increasingly demanding global market, the agri-food industry is forced to constantly find new solutions during the production of healthy food. The technology of ripening fruits and vegetables is gaining more and more importance in modern society. The importance of this technology is reflected in the fact that the semi-finished product is provided with longer shelf life, better transport conditions, facilitates storage, provides adequate processing conditions, provides better quality, ensures the market with continuous supply, provides greater satisfaction of users, reduces business costs, etc. (Socoliuc et al., 2018; Maksimović, 2018).

Banana is a climacteric fruit that is harvested green, where after receiving it in the country of the importer, it is subjected to thermal treatment in special chambers intended for ripening. The treatment of ripening of fruits and vegetables, and thus the economy and final quality of the product, depend on a large number of factors that influence the process, as well as on the decisions for the selection of adequate parameters. External factors that affect the quality of the fruit before, during ripening, and after (in distribution and sale) are: health of the semi-finished product, transport and storage conditions, country of origin, application of agro-technical measures during cultivation, physiological and physical changes in fruit, etc. Apart from external ones, the ripening process is also affected by internal factors that are far more important, such as: ripening temperature, dosing concentration of ripening gas (ethylene), time it takes fruit to ripen, storage conditions, human factor, etc. All factors, both external and internal, are interconnected and the outcome and the course of the process, distribution and sale of bananas depend on their correlation (Dadzie & Orchard, 1997; Dumitraşcu et al., 2013; Chivu et al., 2020).

Today, there is yet no fully standardized, i.e. defined process of ripening green fruit - it depends on the factors that affect the ripening as well as the decisions of the manager. Therefore, on the basis of certain rules and processes from the previous period of work (observation, planning, data collection, etc.), including experience, innovation, training, etc. managers analyze a large number of options, in order to select the most acceptable alternative for achieving business success. The most important issues and decisions faced by managers in the technological process of ripening are reduced to:

1) What is the ideal temperature for thermal treatment of fruit?

2) What is the optimal concentration or dosing time of ripening gas?

3) How much time (or working hours) is needed for successful ripening?

4) How to realize minimal investment of resources and minimal costs in business, achieve minimal commodity losses?

5) How to produce the best quality that will meet the requirements of consumers and provide maximum profit to the company?

Due to the great importance of ripening technology in the world, as well as the need for continuous improvement and modernization of processes, particularly in Serbia, the research has been conducted in the Logistics Distribution Center (Nis). The paper studies the factors (temperature, ethylene, time, kalo, electricity consumption) that most affect the ripening process and production costs. By analyzing 400 ripenings, 4 treatments are defined, where the application of the Simple Additive Weighting (SAW) method leads to a compromise solution and determination of the most acceptable alternative. The objective of this paper is to select the best parameters for ripening of bananas to achieve greater efficiency in business and improve technology, i.e., produce better product quality at lower costs.

Materials and methods

Ripening gas supplied by “MESSER” (Tehnogas, Belgrade) was used to start the process of ripening banana fruit.Ripening gas is a mixture containing 95% nitrogen (N) and 5% ethylene (C_2H_4).The flow of gas into the ripening system is carried out under pressure of 3 bar.The concentration of ripening gas in the decompression rooms for ripening is from 8 to 12 l / m^3.During one minute of dosing of ripening gas in the ripening chamber, about 0.714 l/min of gas is consumed for this type of ripeningplant. The price of a 50 l bottle of ripening gas during the researchaveraged 48.58 € (Euro). For one hour of operation of the decompression room, including heating and cooling, i.e. operation of fans, heaters, compressors, etc., about 8.33 kWh is consumed, which is an average of 200 kWh in one day (24 h). For the ripening of the green banana fruit, the time average of the process is about five days and about 1.000 kWh of electricity is consumed for that period.The average price of commercial electricity for the observed period for small and medium enterprises is 55.84€, i.e. 0.06 €per kWh, to which excise and VAT as well as other benefits that depend on the company should be added.

The “ebro” TLC 720 thermometer (Germany) was used to measure the temperature at the reception.The Bizerba BS 800 CE scale and the Bizerba ST scale (Germany) were used to measure the weight of the fruit.The quality of the fruit was controlled by organoleptic methods and the mentioned instruments by the technologist at the reception.The process of ripening banana fruit is controlled via a central computer and an appropriate software program developed for this type of activity.The temperature of the fruit in the chambers is monitored through a puncture probe manufactured by "Elektrika-Hladilnistvo-Ogrevanje" DOO (Lasko, Brezno).The degree of fruit ripeness was determined by a ripeness degree scale of from 1 to 7: 1) dark green shade; 2) light green shade; 3) more green than yellow shade; 4) more yellow than green shade; 5) yellow color with green tips; 6) completely yellow shade; 7) completely yellow shade with brown spots (Kader,1992).

The influence of factors was examined on the Cavendish banana fruit imported from different countries (Ecuador, Costa Rica, Colombia, Panama, Honduras etc.) and different brands (Derby, Slobana, Chiquita, Sentiliver, Pamela, Amigo, Bonanza, Consul etc.). The purchase price of green bananas for the mentioned period is 0.75€.

Ripening was carried out in a ripening plant with a total capacity of 245.000 kg, which consists of six hermetic ripening chambers and one warehouse for storing green bananas. The capacity of the decompression room for ripening is 20.000kg, which is the value of the goods of about 15.000€ (calculated at purchase price). Ripening plant belongs to the company "MERCATOR S" (Serbia) and is located in the Logistics Distribution Center (Nis).

Depending on the quality of the fruit and the need for processing for market launch, process managers (technologists) set the appropriate ripening parameters with higher or lower values on the central computer: the temperature that the fruit should reach ranging from 17°C to 20°C; ripening gas dosing concentration ranging from 20 to 40 minutes; air circulation, i.e. ventilation of the chambers every three to six hours from 20 to 45 minutes; ventilation blockage from 12 to 24h when the chamber is under gas. Depending on the needs of ripening, they correct the temperature, gas concentration, ripening time, etc.When the fruit reaches the predicted degree of ripeness, the banana is cooled to an initial temperature of 13°C and stored until further distribution.

In the first part of the paper, an analysis of 400 ripeningshaving been conducted during the practical work in the ripening chambers in Nis in the period from 2017 to 2020 was performed.Statistical processingseparated 4 treatments with average values of all ripenings that had the most frequent application in the company's operation.The criteria by which the treatments are grouped are the parameters used by the technologists during ripening in the South of Serbia.Their choice and decision for ripening parameters (fruit ripening temperature, ethylene concentration, air circulation, etc.) were influenced by internal and external factors such as: fruit quality at reception and during storage, weather conditions, seasons, transport, sales and distribution projection, market influence and price, conditions in the storage and in the ripening chambers, etc. The greatest emphasis in the analysis is onthe fruit kalo, i.e. loss (commodity weight loss before and after ripening) caused by fruit weight reduction due to biochemical and physiological changes that take place in the fruit during the ripening process of climatecteric fruit.

The second part presents the application of the Multiple-criteria decision-making (MCDM) to optimize the technological process. Multi-criteria analysis is often used for modern decision-making in the agri-food industry (Srđević, 2003; Talukder et al., 2017; Gésan-Guiziou et al., 2020; Veselinović et al., 2022; Namiotko et al., 2022). These methods are often used to manage risk in the agricultural supply chain (Yazdani et al., 2021; Septiani et al., 2016), for the water resources management in agriculture (Radmehr et al., 2022), selection of agricultural machinery (Blagojević et al., 2012), development of rural tourism (Nedeljković et al., 2022), ecotourism and sustainable tourism (Garabinović et al., 2021), for evaluating the efficiency of agricultural enterprises (Lukić et al., 2021) as well as for assessing the agriculture sustainability (Cicciù et al., 2022; Issa et al., 2022; Talukder et al., 2018; Pantić et al., 2022; Talukder et al., 2017).

The basic stages of the multicriteria method are: determination of appropriate criteria and alternatives, evolution of alternatives, determination of numerical value (weight) for each criterion, use of cumulative functions for determining rank (Pomerol & Barba-Romero, 2000).

The SAW (Simple Additive Weighting) method was used in the paper. From the offered four alternative solutions from the analysis of 400 carried out ripening, the best parameters for green fruit ripening were determined, which have the greatest importance for optimizing the ripening technological process, reducing costs and obtaining fruit of satisfactory quality using the SAW method.

The SAW method is characterized by its simplicity and because of that it is often used for multi-criteria decision making on attributes (Jain, 2013). Another reason for using this method is that it usually gives similar results as the more advanced methods (Blagojević i sar. 2012). The basic logic of the SAW method is to obtain a weighted sum for evaluating the desirability of each alternative within all attributes (Adriiendi, 2015). The SAW method consists of the following stages (Triantaphyllou & Lin, 1996):

- Formation of the decision-making matrix;
- Normalization of the decision matrix;
- Multiplication of the normalized matrix by weighted coefficients;
- Addition of "difficult" parameters for each alternative i
- Determining the best alternative.

The decision matrix (1) has almost the same form for all methods of multicriteria decision making, with data ranking and comparative evaluation (*m x n*) of the set *m* alternative / type *Ai* (*i* = 1, 2, … m) and the set *n* criteria / columns (attributes) *Cj* (*j* = 1, 2, …, n) (Zavadskas et al., 2008) where x_{ij} represents the performance of the *i* alternative in relation to the *j* criterion / attribute, *m* represents the number of alternatives and *n* represents the number of criteria / attributes.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{12} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (1)$$

The decision maker should assign an appropriate weight or weighted coefficient to each criterion, where the following condition must be met:

$$\sum_{j=1}^{n} w_j = 1 \quad (2)$$

The normalization of alternatives in relation to all criteria is done on the basis of the formulas given below, namely: for the maximized criteria (benefit attribute), the following formula is used:

$$r_{ij} = \frac{x_j}{x_j^{\max}} \Big| j \in J^{\max}, \quad i = 1, \cdots, m. \quad (3)$$

While minimized (cost attributes) value is defined by applying the formula:

$$r_{ij} = \frac{x_j^{\min}}{x_j} \Big| j \in J^{\min}, \quad i = 1, \cdots, m. \quad (4)$$

The second step of the SAW method refers to the formation of weight normalization of the decision matrix $V = [v_{ij}]_{m \times n}$, where the value v_{ij} is expressed by the formula:

$$v_{ij} = w_j \cdot r_j, \quad i = 1, \ldots, m; j = 1, \cdots, n \quad (5)$$

The third step of the SAW method is to determine the overall performance index of each alternative. The resulting / aggregate / cumulative indices denoting the total performance indices S_i are calculated according to the following formula:

$$S_i = \sum_{j=1}^{n} v_j, \quad i = 1, \ldots, m \quad (6)$$

The last fourth step is choosing the best (ranked) alternative. Alternatives are ranked in ascending order based on S_i values. The best ranked alternative is the one where Si has the highest value and it expressed by the formula:

$$A^* \in \left\{ A_i^* \mid \max_i S_i \right\} \quad (7)$$

Results and discussion

Temperature is one of the most important factors influencing fruit ripening. Most banana varieties require a temperature of 14.4 to 18°C for commercial ripening (Robinson, 1996; Turner, 1997). Whitehead (2012) states that in order for a green banana to ripen (depending on the quality and condition in which the fruit is currently in), a temperature of 15 to 20°C is required, and a relative humidity of 90-95%, while the CO_2 level must not be higher than 1% to avoid ethylene suppression.

The statistical processing of the parameters of 400 carried out ripening in the Logistics Distribution Center Niš for the period 2017 to 2020 yielded the average values shown in table 1.

Table 1. Average values of 400 carried out ripening for the period 2017. to 2020.

Temperature (^{o}C)	Ethylene (ppm)	Gas dosing time per minute	Fruit ripening time (h)	Commodity loss (kg)
18,43	825,3	27,51	117,2	276,84

Source: Author's calculations

Research carried out in the warehouse for storing and ripening green bananas at the company "IDEA" in Nis, showed that at a temperature of 20°C the fruits reached consumption maturity in 98.9 hours, while at a lower temperature of 18°C it took about ten more hours (110.5h) (Stojanović, 2015). Therefore, the higher the temperature, the faster the process and the shorter the ripening time Whitehead (2012). Depending on the influence and correction of ripening factors (average temperature, ethylene, fruit condition, etc.), the process of ripening banana fruit can take less than four days at a temperature of 18°C, and can be extended to 8 to 10 days at a temperature of 14°C (Robinson, 1996; Turner, 1997). Similar observations were made in this study.

According to Stojanovic (2015), fruits of the Cavendish variety that were exposed to a higher concentration of ethylene (1200 ppm) reached consumingripenessten hours earlier compared to treatment with a lower amount of ethylene (1140 ppm). Ethylene is a plant hormone that initiates and accelerates ripening, stimulates the development of color and taste of the fruit (Adkins et al., 2005). With the increase in the amount of ethylene, all processes within the banana fruit take place much faster (Siriboon Banlusilp, 2004; Kathirvelan & Vijayaraghavan, 2020). Low ethylene concentration of 10 to 50 $\mu L\ L^{-1}$ is sufficient for fruit ripening (Thompson & Seymour, 1982). Ethylene concentration of 1000 $\mu L\ L^{-1}$ and fruit exposure to ethylene from 24 to 48 h are used for commercial ripening (Robinson, 1996; Thompson & Burden, 1995; Paulo et al., 2022). According to Whitehead (2012), ripening of banana fruit can be carried out at an ethylene concentration of 100-150 $mL\ L^{-1}$.

Although Whitehead (2012) pointed out that an ethylene concentration of 100-150 mL L^{-1} is used for ripening, this concentration was not achieved in these areas. But savings have been made compared to the commercial 1000 mL L^{-1} discussed by other authors

(Robinson, 1996; Thompson & Burden, 1995). The reason for the deviation from Whitehead (2012) may be the consequence of insufficiently developed technology in this area, poor airtightness of the chambers, insufficient education of technologists about the process of fruit ripening, etc.

The increase in commodity loss or weight loss is mostly influenced by longer exposure of the fruit to the ripening process, higher ripening temperature and higher concentration of ethylene, which was concluded by different authors (Mariiott, 1980; Evans et al., 2020; Al-Dairi et al. 2023). However, these factors do not always have to be combined to act on the loss. As it can be seen from the paper, commodity loss increases with decreasing temperature, decreasing ethylene concentration but increasing ripening time. At a higher temperature and a higher concentration of ethylene, there may also be a reduction in the ripening time, and the commodity loss may increase, which is a consequence of the action of other by-factors. By-factors may be the ones discussed by the different studies (Thompson et al., 2019; Al-Dairi et al., 2023; FAO, 1989), i.e. the loss of water from the fruit and therefore the loss of weight occurs under the influence of temperature, relative humidity, poor air circulation, physiological, pathological and physical changes.

In this research, conducted in the Logistics Distribution Center Niš, the most used parameters for ripening, i.e. the parameters that gave the best results, are presented in table 2. The parameters were chosen based on the conditions and suitability of the fruit for ripening, i.e. the following were included in the creation: the current state of the fruit (quality), the storage time of the green fruit in the warehouse, the season and weather conditions when the fruit is ripe, the needs of the market, the storage conditions of the ripe fruit and distribution, sales, etc. Considering that the best results in terms of fruit quality and costs were achieved in this way in the given conditions, these parameters will be further used as alternatives in the process of deciding on the optimization of the banana ripening process.

Table 2. Four best alternative solutions (out of 400 conducted ripenings)

Temperature (°C)	Ethylene (ppm)	Gas dosing time per minute	Fruit ripening time (h)	Commodity loss (kg)	Total cost (€)
17,5	1020	34	123	264	283,02
18	960	32	117	222	247,14
18,5	840	28	112	233	250,12
19	810	26	105	245	254,24

Source: Author's calculations

The selection of the best alternative was made using the SAW multi-criteria decision-making method. The parameters from Table 2 were used in the further course to determine the most important set of criteria and evaluation of the alternative. The selection of attributes (influence of *temperature*, *ethylene* concentration, *duration* of the process, and their influence on *commodity* loss and fruit *quality*) was carried out and a quantitative decision matrix was formed (Table 3).

Table 3. Quantified matrix

Name	Temperature	Ethylene	Time	Loss	Total cost	Quality
UoM	°C	ppm	h	kg	€ (Evro)	High-low
Weight	0,09	0,09	0,09	0,21	0,21	0,31
Optimization	min	min	min	min	min	max
	C1	C2	C3	C4	C5	C6
Alternative						
A_1	17,5	1020	123	264	283,02	Very low (1)
A_2	18	960	117	222	247,14	Medium (5)
A_3	18,5	840	112	233	250,12	High (7)
A_4	19	810	105	245	254,24	Low (3)

Source: Authors' calculations based on data obtained from the decision makers

Legend: °C-temperature in Celsius; ppm-part of a million (μL L^{-1}); h-hour; kg-kilogram; min.-minimum; max-maximum; UoM – Unit of measurement.

It should be noted that in this case, a subjective approach was used to determine the weights of the criteria based on the information received from the decision maker, i.e. from the experts (technologists) in charge of the banana fruit ripening process, where the necessary condition is met:

$$\sum_{j=1}^{n} w_j = 1$$
$$\sum_{j=1}^{n} w_j = 0.09 + 0.09 + 0.09 + 0.21 + 0.21 + 0.31 = 1.00 \quad (3)$$

Based on the data from Table 2, and the importance of criteria, the following decision matrix is obtained:

$$D = \begin{matrix} & 0.09 & 0.09 & 0.09 & 0.21 & 0.21 & 0.31 \\ & \text{min} & \text{min} & \text{min} & \text{min} & \text{min} & \text{max} \\ A_1 & 17.5 & 1020 & 123 & 264 & 283{,}02 & 1 \\ A_2 & 18 & 960 & 117 & 222 & 247{,}14 & 5 \\ A_3 & 18.5 & 840 & 112 & 233 & 250{,}12 & 7 \\ A_4 & 19 & 810 & 105 & 245 & 254{,}24 & 3 \end{matrix}$$

By calculating, the best alternative is obtained, that is, the one with the maximum value of S_i, which in this case is the alternative A_3.

$$S = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ A_4 \end{matrix} \begin{bmatrix} 0.539 \\ 0.895 \\ 0.902 \\ 0.685 \end{bmatrix} \begin{matrix} 4 \\ 2 \\ 1 \Leftarrow \\ 3 \end{matrix}$$

It means that the best results are achieved at a temperature of 18.5°C, at an ethylene concentration of 840 ppm, a process duration of 112 hours, which resulted in a commodity loss of 233 kg, average economic profitability and high fruit quality. All ripenings that were carried out in the research successfully completed the ripening process and achieved a value of 4 (ideal color for retail) on the ripeness scale.

The obtained values have slight deviations compared to the research using the TOPSIS method where, in an experiment conducted on a sample of 80 ripenings in the period from 2015 to 2016 in hermetic ripening chambers at the Logistics Distribution Center in Niš, the best quality with minimal investments and losses was achieved at a temperature of 18°C, with with an ethylene concentration of 920 ppm and the time required to complete the process of 120 hours (Stojanović et al., 2017). The deviations are mostly due to the fact that in this research more importance was given to the practical application in relation to the parameters of ripening in idealized conditions, as well as the aspiration to adjust and obtain parameters from a larger sample, which will give greater efficiency in business and better quality of fruit.

No matter how much the top management wants to influence the efficiency, i.e. business with minimal investments with maximum profit, if the fruit of poor quality is produced, as a result there is a decrease in sales caused by deviations from the standard. There is a lower profit, and there will be an increase in the loss of goods due to the write-off of long-kept (unsold) goods. Therefore, although during the research the attention was focused on reducing costs, the basic meaning in production was not abandoned: to preserve the standard and quality of bananas for sales that will cause consumer satisfaction. According to Kader (2002), value and quality assessment are the assessment of the end user. Regardless of the ripening technology, the quality of the fruit is crucial to determine the final price, and therefore influences the consumer's decision to buy the product (Xie et al., 2023).

Larger deviations in terms of the offered solutions from the research may give worse results. Poor parameter selection can affect the process itself, and consequently the storage and sale of bananas. As it can be seen from the paper, even a small correction of the values for alternatives A_4 and A_1, caused certain deviations, which can cause serious problems for a longer period of time. In the ripening process, the management must decide which technological parameters should be followed.

For example, if temperatures are too high - above 25°C, the flesh will soften and the fruit will look as if cooked (Robinson, 1996; Turner, 1997). At the mentioned temperature, the fruit has a rapid color development, but there is a loss of weight (high relative humidity), the shelf life is reduced and the fruit decays rapidly (Marriott & Palmer,1980). For the mentioned reasons, the temperature of the fruit during heat treatment must not exceed 20°C, because it is always higher for 1 to 2°C in the fruit itself compared to the room temperature.In addition to damage to the inner part of the fruit uneven color may occur on the exocarp or skin of the fruit.

Uneven ripening can be a consequence of inadequate ripening technique, insufficient concentration of ethylene, lack of time to which the fruit is exposed, etc. (Whitehead, 2012). At lower temperatures (between 15.5 and 18°C) during the ripening process, the fruit skin gets the best appearance, and the shelf life is longer. However, bananas have a sour taste, so it takes 2 to 3 days for the fruit to taste better (Kader & Mitcham, 2008). Exposure of the fruit to temperatures below 13°C cause damage in the form of darkening of the skin and 'frostbites' on the fruit.

According to Jayanty and Song (2002), insufficient amounts of ethylene can cause uneven ripening. After the fruit ripens, the excess ethylene in the chambers causes the fruit to decay. Therefore, in order to prevent it, it is necessary to remove or inhibit ethylene (Massolo et al., 2011). The reduction of ethylene in the chambers is achieved by more frequent ventilation (circulation of outside air).

It should always be borne in mind during the ripening process that the banana is a climacteric fruit, in which in the final stage of ripening there is a sudden respiratory jump or increase in respiratory intensity, carbon dioxide release, moisture loss, ethylene production, etc. (Abeles et al., 2012). During ripening, many physicochemical changes occur in terms of fruit softening due to the decomposition of the cell wall under the influence of enzymes, hydrolysis of starch, increased sugar, reduced content of organic acids and phenolic compounds, etc. (Fischer & Bennett, 1991). Once started, the process does not stop. Certain factors are sometimes difficult to control and their undesirable effects can have a bad effect on the entire ripening process.The goal of every manager of the technological process of ripening should be focused primarily on the production of a quality and health-safe product, with less consumption of resources that will not threaten the process and violate standards. In this way, the company ultimately achieves better business results and greater business efficiency.

Modernization of technology in the agri-food industry is important because it increases food productivity (Jamroen et al., 2022). This technology is still a novelty in Serbia, it has its advantages and disadvantages, so significant innovative solutions and improvements are needed. Serbia has not so bad technical solutions, however, training of managers and standardization of processes should be carried out. The paper has just sought to provide better practical solutions and expand theoretical knowledge in this area.

Conclusion

The technology of ripening bananas is influenced by many external factors, and internal factors are far more important for the ripening process itselfincluding: temperature, ripening time, ethylene concentration, human factor, etc. The factors of production are interrelated, and the ripening process itself, i.e. the consumption of production elements, fruit quality and economic profitability of the business depend on their correction as well as the decision of the manager which parameters to choose.

From the processed data, it was concluded that the largest cost of the examined factors was caused by kalo of goods, followed by the consumption of electricity and finally the consumption of ripening gas.Although alternative A_2 had better financial results, alternative A_3 gave generally better results and better quality of goods, which was the goal, therefore this cannot be taken as a disadvantage.

In order to modernize and improve the process in this area, to facilitate the decision of managers which of the parameters to apply for successful ripening, an analysis was conducted and the selection of the most acceptable solution was made. The best results in the technological process of ripening were achieved due to the following parameters: temperature of 18.5°C, concentration of dosing of ripening gas of 840 ppm for 28 minutes, time required to complete the process of 112 h, with the commodity loss (kalo) of 233 kg.

In the technological process of ripening green fruit, there is still no ideally defined solution and mathematical method that would give unique parameters according to which ripening will be carried out. This research provides satisfactory and proven practical solutions for the production of a quality product at lower production costs. However, ripening is a consequence of the factors and the current state in which the fruit is, so the manager's decision should be oriented towards that direction.

Conflict of interests

The authors declare no conflict of interest.

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