OLIVE SORTING PROCESS OPTIMIZATION IN DOMESTIC PRODUCTION OR SMALL OLIVE MILLS SYSTEMS

Doctoral thesis - Abstract

for obtaining the scientific title of doctor at
Polytechnic University of Timisoara
in the field of doctorate in Industrial Engineering

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Chapter 1
NEED, UPDATE AND OPPORTUNITY. THESIS OBJECTIVES

1.1. The need, timeliness and timeliness of the topic

Due to the technological evolution in the agricultural segment, in recent years, great emphasis has been placed on the development of mechanized harvesting systems, but with the development of these harvesting systems has appeared the need to sort harvested products, hence the problem of developing and implementing systems. smart sorting.
The harvesting process can be considered as one of the most important events in the life cycle of plants. It is applied at the end of fruit development and the beginning of its deterioration / aging. After harvest, the fruits, except those that continue to ripen (ripen) and after harvest, have the highest quality, but also the highest economic value, which subsequently involves the use of the most appropriate post-harvest technology to maintain the highest quality level.
Starting from these needs, the thesis studies the current methods of the sorting process as well as the optimization of the olive sorting process, with a possible implementation of other fruits / vegetables that can be identified by color, thus determining their degree of maturity.
By optimizing the sorting process, it is possible to streamline the quality of olive oil, as well as the quality of olives intended for actual consumption and can reduce losses due to manual sorting (human error, delayed sorting, etc.).

1.2 The objectives of the thesis

The main objective of the doctoral thesis is to optimize the olive sorting processes in order to increase economic efficiency and improve the quality of the final product.
From this main objective we can deduce the following secondary objectives, namely:
1. Analysis of the current state of the olive sorting processes;
2. Analysis of the main sorting methods;
3. Analysis of the evolution of olive colors in different stages of maturity;
4. Analysis of the geometric shape of olives;
5. Identifying efficient sorting processes;
6. Identifying the factors that influence the sorting to determine the parameters that influence the sorting;
7. Determining the influences of the sorting process on the quality of olive products (oil and other by-products).

The thesis aims to optimize the process of sorting olives in individual production systems or in small enterprises, computerization of sorting methods by entrepreneurs, thus helping researchers to develop appropriate, efficient and economical sorting devices. Through these elements it is possible to identify and implement optimal sorting systems.
In order to achieve the proposed objective, a case study of the sorting process was carried out, through an analysis of olive sorting methods, in Greece, and based on the experimental results, an automatic sorting prototype was proposed, based on color / camera, making it an efficient and economical device.

Chapter 2

ANALYSIS OF THE PROBLEMS OF THE OLIVE SORTING PROCESS

2.1 Brief history

Olives are the fruit of the olive tree. The olive tree is a tree known in the Mediterranean basin since antiquity (about 6000 - 7000 years ago), making it one of the oldest cultivated trees in the world. From antiquity to the day, it our olive tree is grown mainly for its valuable fruits, olives, from which the olive oil and table olives.
Consumption of olive oil as well as table olives can bring many benefits to the human body, namely:

- Maintaining a healthy heart; research in recent years has shown that people on a Mediterranean diet are less likely to suffer a stroke, and heart disease and blood pressure problems are also significantly reduced; this seems to be associated with the consumption of olives and olive oil, which is due to the fact that olives have a high content of polyphenols that help relax and dilate the arteries, thus maintaining blood pressure within normal limits. At the same time, olives are rich in antioxidants that neutralize the novice substances in the body, thus protecting human cells; In addition to the above, it should be borne in mind that olive oil increases the level of good cholesterol in the blood, ie high-density cholesterol (HDL) which eliminates excess bad cholesterol, thus lowering low-density lipoprotein (LDL) cholesterol;
- A healthier body is based on oleic acid and antioxidants (especially oleocanthal ui) , which are found in extra virgin olive oil, which act as natural anti-inflammatory agents.

2.2 Olive fruit morphology

Olives have been known and consumed in various forms since antiquity. There is a wide variety of varieties, which also implies a different type of dimension (figure 2. 1). Thus, olives can be small (1.2-2.6 gr.), good for oil, medium (2.7-4.2 gr.), good for both consumption and oil and large (4.3-10.5 gr. or more), good for consumption.

Fig. 0.1. Different types of olives

The color of olives, in most varieties, is given by the degree of maturity reached. Thus their color varies from an intense green to an intense black. At the beginning of the ripening process, the olives are green, in the middle of maturity they have a purple-brown color, and when the maximum maturity level has been reached, the olives have an intense black glow (figure 2.2).

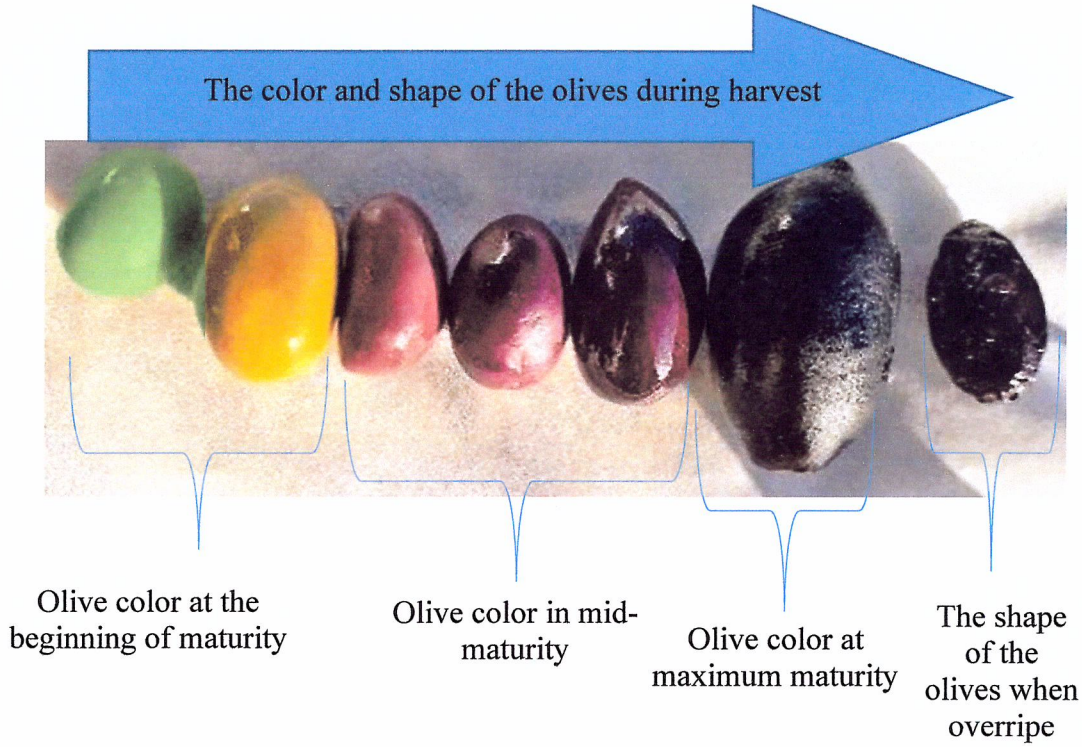

Fig. 0.2. The color and shape of the olives

2.3 Functional and structural analysis of the olive sorting process (OSP) in order to optimize

Sorting is the second important stage in the process of capitalization of the agricultural product, after the harvesting stage, because it contributes to increasing the quality of the finished product. In the case of olives, sorting should be done as soon as possible, immediately after harvest, due to the fact that the olives deteriorate / ripen fairly quickly after harvest.
The sorting of the olives includes the identification, sorting and intermediate storage steps, if necessary.
The optimization of the olive sorting process (OSP) is based on an analysis of the stages of information, sorting and intermediate storage of olives. This analysis should be performed prior to sorting process (Fig 2.3).

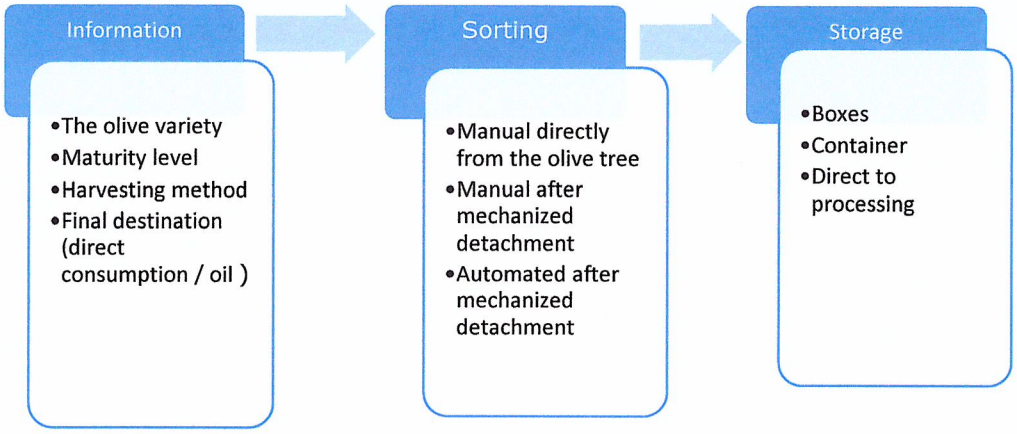

Fig. 0.3. The functional principle of the OSP

2.4 Key functions and factors in the olive sorting process (OSP)

In recent years, there has been a development of automated sorting systems, a development due to market competitiveness, lack of labor and increasing food consumption. Thus, if until 20 years ago the manual sorting of olives was mainly used, in recent years a series of special automatic sorting systems have been developed. These systems are still in the development / research stage and are expensive, being inaccessible to the vast majority of small developers.
Following the study conducted in Greece, we identified the following methods of sorting olives:

- ***manual sorting*** is a common method of sorting olives. This is due to the fact that it is the most effective method in terms of the quality of olives obtained. No mechanical devices are used for this method, and the sorting is performed by the human operator.
  Manual sorting can be:
  - manual sorting directly from the tree;
  - manual sorting from the ground;
  - manual sorting at the collection center;
  - manual sorting on conveyor belts.
- ***s ort semi-mechanized*** is the type of sorting is based on automatic sorting / mechanized by the size of the olive and the manual sorting by color. It is divided into three distinct areas, namely: the area for removing leaves, twigs and other third-party objects, washing, followed by the sorting area and the sorting area by size, followed by the manual sorting method;
- ***automated sorting*** has emerged in recent years as a necessity of market requirements: higher productivity and better quality of the finished product. However, despite technological development, there are still industries that

use manual sorting to avoid high operating and maintenance costs, such an industry is also the olive industry.

In Greece, the vast majority of processors, but also of olive growers are represented by small developers, for this reason , most often , manual sorting is used.

2.5 Practical study on the critical analysis of technical solutions and current olive sorting systems in Greece

This analysis was carried out in the regions of Macedonia (northern Greece) and Thessaly (central Greece) [80], where several olive groves were studied in 2017 (November and December) and 2018 (November and December).). The period of November and December was chosen because it is the optimal period for harvesting and sorting. Thus, it is possible to study and analyze the sorting process at several companies / enterprises whose field of activity is olive processing.

The results of this analysis show that in this area, the olive variety for consumption (fruit is larger) predominates, followed by the other hybrid varieties, hybrids being generically called dual-purpose olives (for oil and consumption) . Thus, the consumption varieties and the hybrid ones represent a total of 77% of the orchard capacity, while only a percentage of 23% is represented by the olives destined for oil, figure 2. 4 . These researches have shown that regardless of the variety of olives, in order to obtain high quality products that offer competitiveness in the consumer market, it is necessary to introduce the olive sorting phase in the continuation of the technological process.

The field analysis found that, in only three cases, it was not necessary to carry out the olive sorting operation, being olives, whose destination is to obtain oil, oil which was not required a premium quality. In all other cases, sorting is done manually (figure 2.5), either on site or at a warehouse (own or a collection-processing center), there are 2% cases when sorting is not necessary. No automatic sorting devices are currently used.

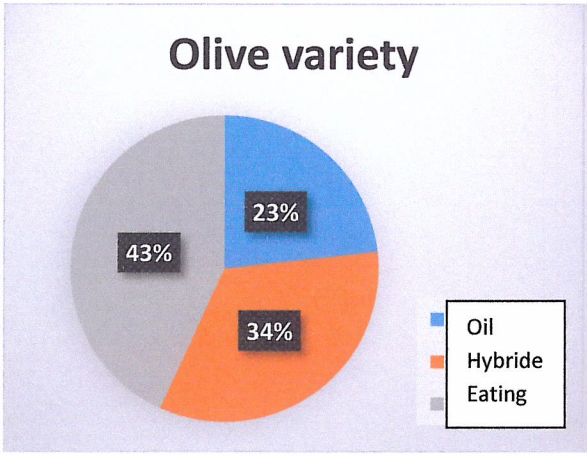

Fig. 0.4. Olive variety

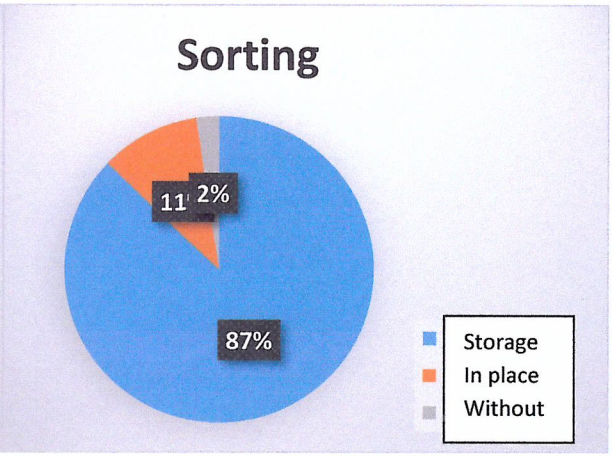

Fig. 0.5. Sorting

When sorting is performed at a warehouse, then we can find two sorting methods (figure 2. 6), one manual on the work table and one semi-automatic, also by manual selection, but on the conveyor belt, there are also 3 % cases where sorting is not necessarily complicated (statistically significant).

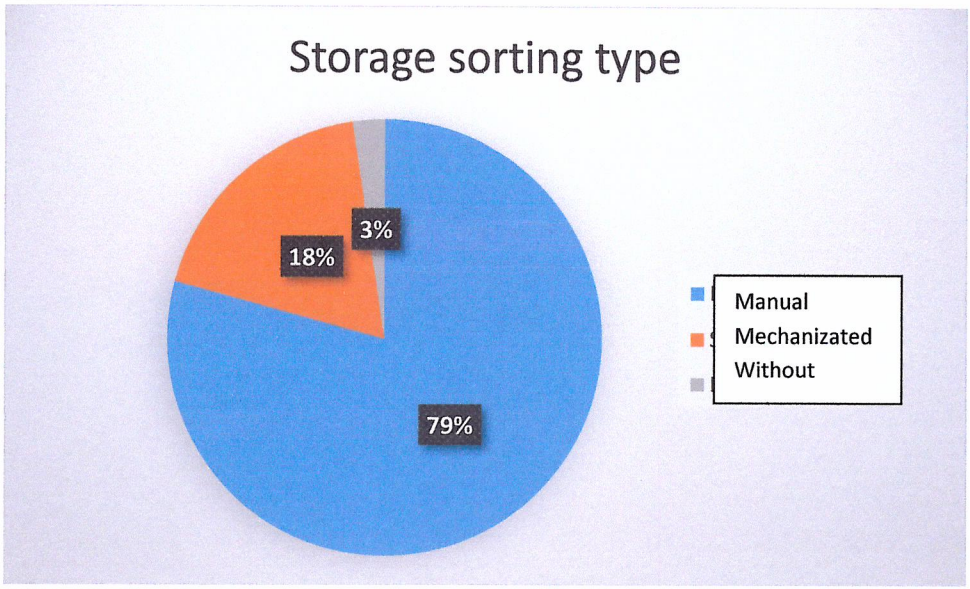

Fig. 0.6. Sorting type at the warehouse after harvest

Chapter 3

EXPERIMENTAL RESEARCH ON THE DESIGN OF AN EXPERIMENTAL MODEL OF THE OPTICAL SORTING EQUIPMENT OF OLIVES

3.1 Establishing the conceptual elements based on the value analysis

The value analysis on the olive sorting process was performed in order to identify technical and economic data that can improve the sorting process.
In this part of the research, we study and analyze the cost of the sorting process and the profitability of the sorting process.
The value analysis was applied, in part, to all current sorting methods encountered in Greece, namely:

- Manual sorting directly from the tree;
- Manual sorting from the ground;
- Manual sorting in the warehouse;
- Semi-automatic sorting on conveyor belts.

For this analysis 1 was used, namely the production given by an olive grove with an area of 1.2 ha, with a number of 500 olive trees, with an annual production of 30,000 kg of olives.

3.2 Presentation of the logical scheme of the sorting prototype

Logical diagram (figure 3. 1) for designing the sorting prototype. Thus, the system should detect the olive on the conveyor belt, otherwise the cycle is repeated until the olive is detected. After detection, a color analysis is performed, if the olive is recognized as green, it is released from the conveyor belt in the collecting basket 1. If it is not detected as green, then the olive is analyzed again for black, if it is noticed as black, then it is released in the collector basket 2. If the olive is not noticed in black, then it is released in the collector basket 3 and the cycle will be repeated.

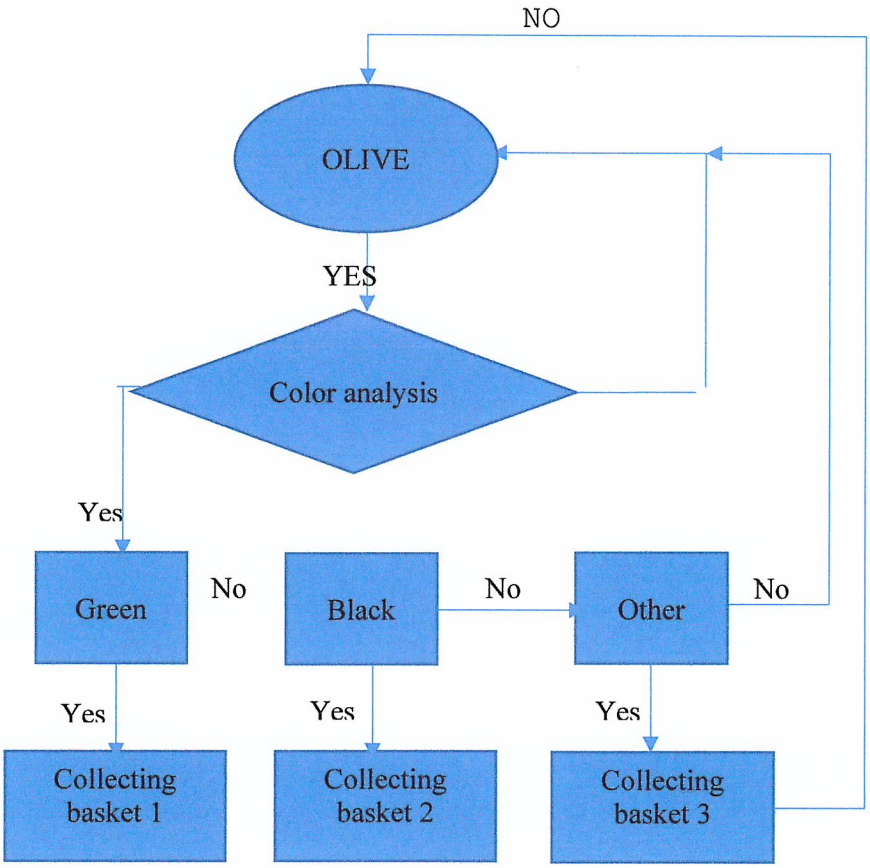

Fig. 0.1. Logical diagram

3.3 Conclusions

The olive sorting operation is necessary for both the production of edible olives and the production of olive oil. For this reason, the sorting stage is a vital stage in the technological process, depending on the quality of the products obtained, whether it is olives for consumption, or whether it is olive oil.

Nowadays, the following sorting methods are used:

- Manual directly from the tree;
- Manual on the ground;
- Manual at the warehouse;
- Semi-automatic on conveyor belts;
- Automatic after image recognition (still in development).

The manual method directly from the tree is a very precise method with a high quality level, but it is very slow and expensive if you want a quick sorting (by hiring several service people).

The manual method on the ground is similar to the method of manual sorting directly from the tree, from a qualitative point of view obtaining approximately the same results, but it is also expensive, with the difference that it is a bit faster and with the mention that we have olives shaking or natural (baked).

The manual storage method is a method based on the raw material brought to the warehouse, olives, which facilitates sorting. This is a faster method than the first two methods.

The semi-automatic method is a method more and more often used by larger companies , but also by some of the small entrepreneurs. It is a much faster method than the methods presented above, it has the advantage that olives can be washed and sorted by size, thus reaching the stage of sorting by color only olives that meet the minimum quality requirements.

The automatic method is, in theory, the most efficient method. This method is still under development even though there are some devices on the market that use image sorting. The colors of the olives, as well as their type and size vary depending on the variety and the degree of maturity reached at the time of harvest, which makes it very difficult to recognize them by images.

The ideal would be an automatic sorting with a low cost of the machine and with a high productivity.

Chapter 4

EXPERIMENTAL RESEARCH ON THE OPTIMIZATION OF THE OPTICAL PROCESSING OF OLIVES

In this stage of the research, the aim was to optimize the sorting process by implementing optical recognition systems in two distinct stages.
Stage I - In this stage (subchapter 4.1) experimental research is performed based on the use of color sensors in the sorting process.
Stage II - In this stage (subchapter 4.2) experimental research is performed based on the use of images taken from the video camera in the sorting process.

4.1 Experimental research on optimizing the sorting process with color sensors

In this stage of the research, a sorting prototype was made, figure 4.1. in order to determine the optimal accuracy and speed.
The prototype (Figure 4.1) sorts the olives by means of two black (4) and green (5) sensors, the olives being taken from the feeding point (7) and transported in front of the sensors by means of the conveyor belt (3). With the help of the extractor (6) the olives are pushed into the collecting trays, the collecting tray for black olives (1) and the collecting tray for green olives (2). The processor (8) offers the possibility to set and modify the working parameters

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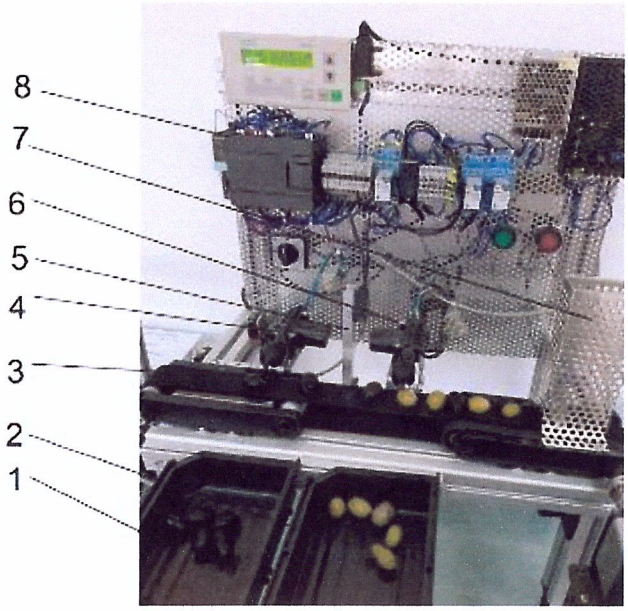

Fig. 0.1. Olive sorting prototype

The prototype processor (8) has been programmed to operate when the color sensors (4 and 5) detect an olive of a certain color and to transmit control of the extractor for that color.

This experimental equipment was made in 2017-2018 in order to sort the olives by color using color sensors.
The principle of operation of the prototype of the apron is based on color sensors is as follows: the olives with the help of the conveyor belt pass in front of the color sensors. The first sensor to detect a green olive gives a signal to stop the conveyor belt and release the olive from the conveyor belt. If no olive is detected then the conveyor belt remains in operation. This cycle is also valid for the second sensor, which detects black olives.
The testing of the prototype was performed with black and green olives placed on the conveyor belt at a predetermined distance between them, and the speed of movement of the conveyor belt being variable. Thus, in the first test we used a low travel speed of 0.04 m / s together with a greater distance between the olives, namely 5 cm, and in the following tests we will change these parameters several times, reaching to increase the speed. travel distance up to 0.251 m / s and reduce the distance between the olives to a minimum. In all the tests, in part, 100 black olives and 100 green olives were used.

4.1.1 Results and conclusions

Following this stage of the research we have generated two important conclusions.
Conclusion I, when I used olives of very close colors, of the same variety and from the same period of maturity (green and black) the results were satisfactory, but also indicating the fact that, with the increase of the conveyor belt speed, the errors of recognition obviously leading to an error sorting, figures 4.3 and 4.4.

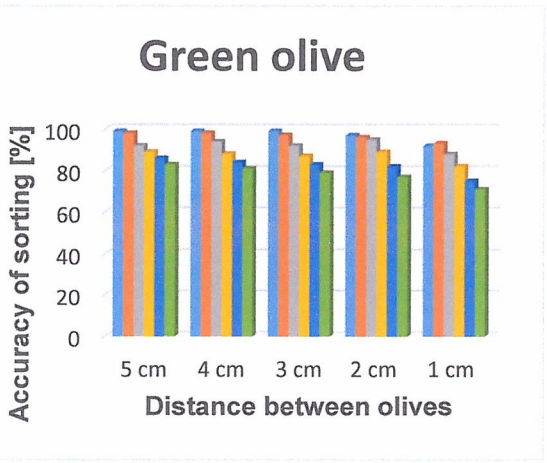

Fig. 0.2. Accuracy of sorting green olives

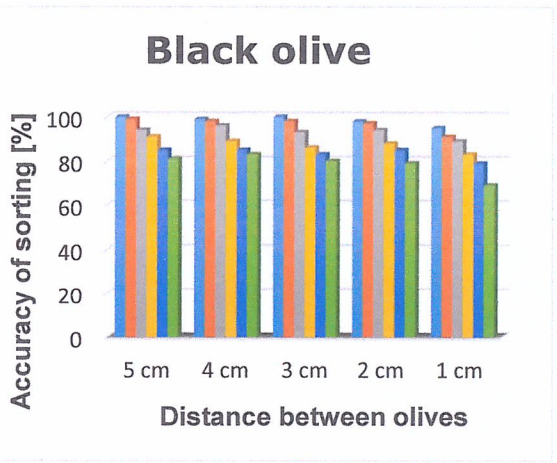

Fig. 0.3. Accuracy of sorting black olives

It can be seen that, in the case of green olives, the sorting accuracy at higher speeds (0.218 m / s and 0.251 m / s) decreases around 80% where we have the distance between olives of 5 cm, 4 cm and 3 cm. Also, at the same distance between the olives, but at lower speeds (0.04 and 0.08 m / s) the sorting accuracy is high with values between 97% and 100%.
In the case of black olives, the results were similar, namely a low accuracy at higher speeds (0.218 and 0.251 m / s) for all values of the distance between the olives less than 1 cm where the accuracy fell below 70%. And at travel speeds of 0.04 and 0.08 m / s with a distance of 5, 4 and 3 cm the accuracy being between 98% and 100%.

4.2 Experimental research on optimizing the sorting process by color analysis

In this stage of the research, the sorting equipment, prototype, was redesigned and improved for a better sorting efficiency by color recognition.
The prototype was made in 2020 and is based on the principle of color recognition using a webcam that poses the olives and further analyzes the color, figure 4.5.

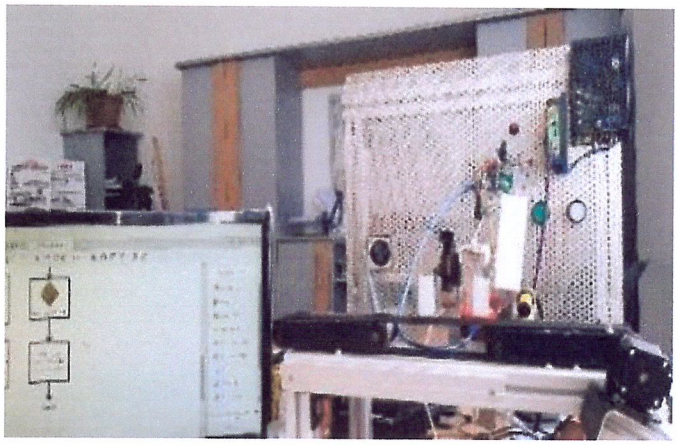

Fig. 0.5. Prototype smart sorting system

The realization of the prototype was based on the development scheme of the prototype, figure 4.6 and on the logical scheme.
The development scheme comprises two distinct phases. The first phase, being the development phase from a technical point of view (hardware), and the second phase being the development phase of the program (software) for analysis and color recognition.

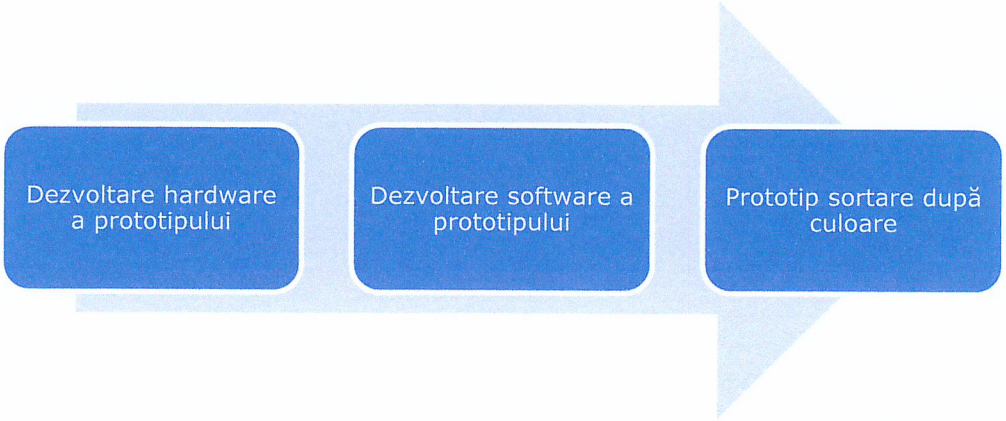

Fig. 0.6. Scheme development of the prototype of recognition of color

4.2.1 Results and conclusions

Intelligent recognition prototype version, which has developed a learning program color (shades of color that must recognize) resulted in an improvement of the device (prototype) sorting.

All the tests had promising results , and the recognition rate was higher than 95% for black and brown olives, and for green olives reaching up to 100% on the two recognition areas.

Of the two methods, namely the three-zone sorting method and the two-zone sorting method, the most efficient method was the two-zone sorting method, the results of the tests performed being found in comparative tables 4.1 and 4.2.

It is May can be concluded that the most effective combination is the method of sorting the two clearances, in which the green color should be sorted on the one of the recess, the results of tests showing an accuracy of 100%.

Table 0.1 Table comparison between the two methods of the recess, with one zone for extracting olive

Speed [m/s]]			0,04	0,08	0,125	0,167	0,218	0,251
			Sorting accuracy [%]					
Zone 1	With three clearing areas	B	99.5	99.5	98.5	98	99	95.5
		G	99.5	100	98	99	99	99.5
Zone 1	With two clearing areas	B	99	96	98	99	97	96
		G	100	100	100	100	100	100

G-green; B-black.

Table 0.2 Table comparison between the two methods of the recess, with two zone for extracting olive

Speed [m/s]]			0,04	0,08	0,125	0,167	0,218	0,251
			Sorting accuracy [%]					
Zone 2	With three clearing areas	N	98.5	99	98	96.5	98.5	94.5
		V	100	99	99.5	99	99.5	99.5
Zone 2	With two clearing areas	N	100	100	100	100	100	100
		V	100	100	100	100	100	100

**Clearance zone 2 for the two-clearance method is zone 3 of the three-clearance method*

G-green; B-black.

Table 4.3 shows the times required to sort between the two methods. For the method with three clearance zones, the sum of the time required for sorting on clearance zone 1 and 2 was calculated, and the table shows the average times for the two sorting methods.

Table 0.2 Table comparison between the two methods of the recess, with two of the clearance

Sorting time in the method with three zones of clearance [s]	Sorting time in the method with two zones of clearance [s]
2.37	0.83

Thus it can be seen that the fastest method is the sorting method with two clearance areas.
In conclusion , it can be said that the sorting method with two sorting zones is the most efficient method between the two, and if the green color is analyzed on the clearance zone 1 , then we have a 100% sorting percentage.

Chapter 5

CONCLUSIONS. PERSONAL CONTRIBUTIONS AND RESEARCH PERSPECTIVES

With the technological development of recent years, there have been applications for technological progress in automating agriculture. Thus, lately more and more resources have been allocated to the improvement and development of new systems as efficient as possible in the agricultural field. These include automatic fruit and vegetable sorting systems . The main goal of these automatic development systems is to make the production lines as efficient as possible with the lowest possible losses and to increase the quality of the finished products , with a high coverage of the needs of the consumer market. The research focused on the study of olive sorting (especially the sorting of black and green olives) through automatic systems based on color recognition.

For a stockings with a more efficient sorting of olives by color , sorting was bad lysed using the color sensor and high definition cameras .

The color analysis was performed by using the special spectrophotometer, but also in real time, by using the high-definition image recording camera.

Based on the color analysis, the sorting device was programmed so as to optimize the sorting by increasing the efficiency of the automatic sorting.

In the end, we conclude that the research confirmed the initial predictions, namely that the sorting activities require a special approach to the management of such systems.

5.1 Personal contributions

The paper presents a significant number of personal contributions, both theoretical and applied, but especially experimental, based on a prototype sorting, but also on a documentary study and all theoretical and experimental research conducted during the research period. .

5.1.1 Theoretical contributions

The most significant theoretical contributions in this research are:
- determination of fruit ripeness based on color in real time;
- extension of research based on automatic sorting, depending on color and to other categories of fruit;
- new research possibilities on sorting devices based on fruit color, but also on other activities that can lead to better productivity by adding treatment, washing, processing operations and so on;
- analysis of images, olives, in real time;
- development and implementation of a program to determine the maturity of the fruit based on the color spectrum;
- development of a prototype based on the parameters of the theoretical study, but also on the basis of the experimental study on the color of olives.

5.1.2 Experimental contributions

This paper offers many experimental contributions, and the most important are:
- study on the color of olives;
- the study of color recognition by means of the color sensor;
- study of color recognition through the camera;
- analysis of olive colors using a spectrophotometer;
- determination of working parameters for automatic sorting;
- PSM analysis in order to optimize olive sorting systems;
- development of a program for determining the colors of the olives so that the colors are defined correctly, intended for sorting;

- implementation of the optimal olive sorting system;
- development of prototypes for sorting olives.

5.1.3 Application contributions

- reduction of production costs, by automatic sorting of olives, both for edible olives and for those intended for oil processing;
- improving and optimizing sorting;
- optimal establishment of sorting parameters;
- definition of the colors in the color spectrum, the reference according to which the olives are to be sorted;
- increase the sorting speed;
- improving productivity, in particular in terms of quality, by developing optimal PSMs for each olive variety.

5.2 Perspectives for further development of research

A number of new directions have been developed in this research, such as:
- development of research on other fruits, fruits in which by studying their color can determine the level of maturity and their nutritional values;
- development of experimental research for color recognition by using the webcam;
- the possibility of starting new research on automatic fruit sorting systems;
- the possibility of determining the existence of defects, deterioration, improper development and pathogens on fruits by developing image analysis systems;
- development of an automatic sorting prototype based on color recognition of different types of fruit.

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