# Development of a blueberry sorting machine

# Desarrollo de una máquina seleccionadora de blueberry

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**Abstract**

In the municipality of Zacatlan de las Manzanas located in the Sierra Norte of the State of Puebla, many families are dedicated to grow blueberry, basically at the time of cutting the fruit or harvesting the area is accessed with baskets for collection, then begins the process that focuses on the selection of the fruit by size, this task is very late and therefore tedious especially if it is done without using tools, on the other hand should take care of the handling of the fruit to be kept in optimal conditions. The objective of this article is the development of a blueberry sorting machine from the design of a mechanical-electrical system using CAD software and simulation, to its operation to ensure the correct selection, better handling of the fruit and reduce time and movements, in order to improve the process and scheduled delivery to the customer. With this project it is intended that the blueberry sorting machine has advantages over the manual selection of the fruit in the size classification by means of a simple system for this process.

**Machine, Sorter, Blueberry**

**Resumen**

En el municipio de Zacatlán de las Manzanas ubicado en la Sierra Norte del Estado de Puebla muchas familias se dedican a cultivar "blueberry", básicamente al momento del corte de la fruta o cosecha se accede al área con cestos para la recolección, posteriormente se inicia el proceso que se enfoca en la selección del fruto por tamaño, dicha tarea es muy tardada y por lo tanto tediosa sobre todo si se realiza sin utilizar herramientas, por otro lado se debe cuidar la manipulación del fruto para que se conserve en óptimas condiciones. El presente artículo tiene como objetivo el desarrollo de una máquina seleccionadora de blueberry desde el diseño de un sistema mecánico-eléctrico utilizando software de CAD y simulación, hasta su puesta en operación para garantizar la selección correcta, una mejor manipulación del fruto y reducir los tiempos y movimientos, con la finalidad de mejorar el proceso y entrega programada al cliente. Con este proyecto se pretende que la máquina seleccionadora de blueberry presente ventajas respecto a la selección manual del fruto en la clasificación por tamaños mediante un sistema sencillo para este proceso.

**Máquina, Seleccionadora, Blueberry**

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## Introduction

Bilberry (Vaccinium myrtillus L.) is a well-known deciduous dwarf shrub that grows mainly in cold temperate regions and mountainous areas of Europe and Asia (Zorenc et al., 2017) and in recent years the cultivated area of this species has increased markedly as a result of the high demand for the fruit (Intagri, 2016).

Today, blueberry cultivation is widespread in countries such as China, Japan, Chile, New Zealand, Argentina and Mexico. Globally, the area has increased by approximately 15,000 hectares in just 4 years from 2010 to 2014. This growth has been observed in Mexico, driven mainly by the benefits of being close to the U.S. market and by the climatic diversity, as only in 2015 a production of 15,489 tons with an export value of US$121 million was reported (Intagri, 2016). The climatic conditions and proximity to the demanding market make blueberries a highly profitable crop in Mexico.

Blueberry is a berry type fruit in a spherical shape of one or two centimeters, which has many properties: "It is a fruit rich in fiber, astringent, diuretic and also has vitamin C and vitamin K. It is a natural antioxidant and also helps maintain optimal brain function and vision. It is a natural antioxidant and also helps to maintain in optimal conditions the functioning of the brain and eyesight," he added (González, 2012).

In the Sierra Norte of the State of Puebla, particularly in the municipality of Zacatlán, they have focused over time on producing blueberries, which is why in 2009 they became the first in the entire region to receive the certificate for organic crops in their entirety: "Currently, they are the largest producers in Puebla, with 88 tons exported to the United States and Canada" (González, 2012). The growing demand for products in international markets makes compliance with increasingly demanding quality standards mandatory, which is why producers in these communities have found it necessary to acquire machines that compensate for the lack of labor, save time and increase the quality of the final products compared to conventional manual processes (Shimabukuro, 2020).

Several methods have been developed for fruit sorting according to a variety of criteria, based on both mechanical and electronic principles. Therefore, there is a need for quality assurance in the blueberry sorting process prior to packing, especially for small and medium-sized growers (Shimabukuro, 2020).

The constant search for innovative solutions in the agricultural industry has led to the development of mechatronic technologies that optimize fruit selection and harvesting processes. In line with this trend, the thesis entitled "Design of a mechatronic system for blueberry selection" by (Rudas, C. A. 2015), represents a valuable contribution in the search for improvements in the efficiency and precision of blueberry selection in the context of the Pontificia Universidad Católica del Perú.

Mechatronic systems for blueberry sorting by size are currently available. For this purpose, a search of the state of the art is presented: bibliographic references, utility models and patents of invention on sorting machines dedicated to blueberry sorting.

## Mechanical methods

Diverging rollers or belts: Two rotating rollers, inclined with respect to the vertical and separated from each other, transport the fruit in the central space. The separation at the upper end is smaller than at the lower end, resulting in a variable space between rollers. Thus, small fruits will fall before large fruits, giving the possibility of sorting them in multiple size ranges.

Variable spacing rollers: Multiple free-spinning rollers form a transport platform for the fruit. The rollers are coupled to a scissor-type chain, which generates the travel motion by means of a motor. The chain is contained in guides with decreasing spacing, so that the scissor links compress vertically and expand horizontally, causing the rollers to progressively separate.

Screens, meshes, sieves: A plate with holes of variable diameter (sieve) or a wire mesh, allow to separate fruits of larger and smaller size than the size established in the mesh or sieve.

**Computer visión**

From an image of the fruit captured online, parameters associated with fruit size can be estimated, among the most common being diameter, projected area, length of longitudinal and transverse axes, and aspect ratio (Roberto Shimabukuro, 2020).

In the field of ecological research, the study by (Chang, Wang, Yang, and Qin 2023) stands out as a significant breakthrough in the assessment of ecological suitability of blueberries. Through their work entitled "An improved CatBoost-based classification model for the ecological suitability of blueberries", the authors demonstrate the application of advanced machine learning techniques in predicting the suitability of environments for growing this valuable fruit.

In the dynamic field of food research, the collaborative work of (Lippi, Senger, Karhu, Mezzetti, Cianciabella, Denoyes, Chiara et al. 2023) stands as an essential contribution. Through their study entitled "Development and Validation of a Multilingual Lexicon as a Key Tool for Sensory Analysis and Consumer Testing of Blueberry and Raspberry Fruits," the researchers have charted a path toward a deeper and more accurate understanding of the sensory characteristics of these prized fruits.

The purpose of this project is to detail a methodology for the development of a blueberry sorting machine according to its size, by means of a mechanical-electrical system. The machine presents a mechanism that fulfills an adequate dosage by size and the preservation of the texture of the fruit. This mechanical system was developed using SolidWorks design software, meeting the following specific objectives:

– Collect information on fruit specification.

– Collect information on the standards or type of fruit grading.

– Propose a design for the construction of the sorting machine.

– Design the prototypes of pulleys for the elaboration of the machine.

– Investigate the type of belts for the elaboration of the machine.

– Investigate the type of materials to cover the machine.

– Analyze the cost of materials for the machine.

– To facilitate the process of fruit size classification.

**Methodology**

Most of the inhabitants of Xoxonacatla, Zacatlan, Pue., are dedicated to the harvest of blueberry, this implies that they must apply certain processes to the fruit, one of the manual processes that apply is the process of selection of size and category, this process will invest considerable time and complicated because they do it manually, another of the criteria to be taken care of is to maintain a type of powder called (blum), so that the fruit remains in optimal conditions.

The main objective of this project is to design and integrate a blueberry sorting machine, using design and simulation software, to ensure the correct selection, better handling of the fruit and reduce time and movements, in order to improve the process and scheduled delivery to the customer.

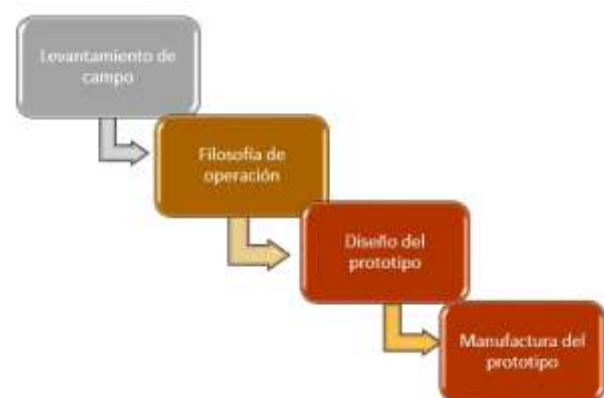For the development of the prototype, the methodology shown in Figure 1 was chosen.



**Figure 1** Block diagram of the procedure to follow
*Source: Own Elaboration*

A.    Field survey

Based on the request made by the people interested in the sorter, a type of mechanical-electrical machine is required that can sort blueberry fruit by size, with the objective of reducing a sub-process applied to the product.

To this end, information on the product was gathered and interviews were conducted with producers in order to have a better view of the characteristics required for the proposed design of the sorter.

According to the information obtained, the requirements for the recruiter are as follows:

– That it has the capacity not to damage the fruit.

– Affordable machine in terms of cost for producers.

– Easy to use.

– It must have a durability guarantee of at least 1 to 2 years of service.

– To have 4 types of categories in the selection of fruit size.

– Preserving blum in fruit

B.    Operating philosophy.

In this process of researching the characteristics and specifications of blueberry fruit, the standards and types of classification were collected, seeking information from national standards.

For the purposes of the Standard, the terms established in Mexican Standard NMX-FF-129-SCFI-2016 apply, in addition to being complemented by the following:

*Basket:* Six-sided plastic container with regular shapes that form nets, the upper side being free of these. The dimensions of the basket are: lower base 6.5 cm, upper base 10.0 cm x 10.0 cm, and height 6.0 cm with an approximate capacity of 250 g to 454 g.

Table 1 shows the size standards established for various fruit derived from the fruit:

| Size | Equatorial diameter range (cm) | | |
|------|------|------|------|
| A | 20 mm | or | More |
| B | 16 mm | to | 18 mm |
| C | 10 mm | to | 14 mm |
| D | 4 mm | to | 8 mm |

**Table 1** Size specifications
*Source: Own Elaboration*

C.    Prototype design

After studying and gathering the necessary information on the requirements and operating philosophy for the blueberry sorting machine, we proceeded to present the prototype of the machine using SolidWorks design software (see Figure 2 and Figure 3), based on the characteristics and observations of the producers.

To this end, the structural, mechanical and electrical model was designed to subsequently build the prototype and run the static and dynamic tests in order to evaluate its performance and, if necessary, reengineer the system.



**Figure 2** Final design of the prototype in SolidWorks
*Source: Own Elaboration*

**Figure 3** Final rendering of the complete machine
*Source: Own Elaboration*

D.      Prototype manufacturing

The following components are used in the manufacture of the sorting machine (See Figure 4):

a.      24-gauge food grade stainless steel sheet, this is used as the coating parts for the equipment.

b.      24 gauge food grade stainless steel tray, primary use is for harvesting the highest quality product with premium designation.

c.      Naylamid pulleys with an internal diameter of 1 inch and a thickness of 0.9 mm, this has a long working life, this material is widely used in heavy duty machinery.

d.      Floor bearing 1 inch Ucp205-16.

e.      7 inch aluminum pulley type B, this pulley is used mechanically to slow down the motor speed.

f.      1% inch steel PTR pipe.

g.      Three-phase electric motor of 1 horsepower.

h.      Food grade stainless steel sheet separator. This separator's main function is in the selection area, it plays a very important role, since it prevents the product from mixing with the different sizes of fruit already selected.

i.      On, off switch model SP-330 3P 30 A of 3.7 KW, this switch is for industrial use for a better handling of the equipment and for protection.

j.      24 gauge food grade stainless steel tray, this container's main function is the retention of the product in its initial phase.

k.      Heavy duty 3x14 gauge cable, which avoids any type of breakage of the cable.

l.      Type A39 type B band.

m.      1 ¼ inch PTR rubber buffer, the main use is to keep the equipment stable and avoid vibrations.
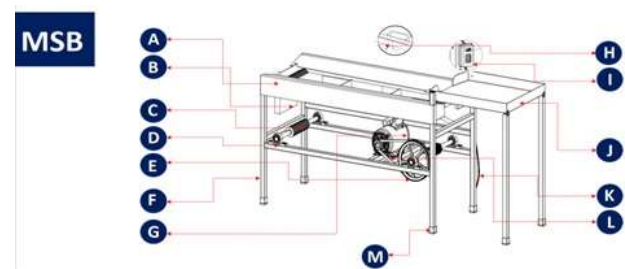


**Figure 4** Important components of the sorting machine
*Source: Own Elaboration*

**Results**

The process starts at the feeder (starter tray) which contains and supplies the blueberry fruit. The tray supplies the fruit that goes to the circular belts (Polycord) that are fed with the motor (WEG 14347787) that pass through a pulley transmission in speed reduction mode, the speed should not be manipulated as this affects the sorting process.

The belts transport and at the same time make the selection process depositing the fruit in one of four selections separating them by sizes (calibers), the fruit when falling through these separators are transported when falling on a stainless steel sheet at an angle to the right side to fall into a final container, In this are three of the four types of selection and the fourth selection point is at the end of the conveyor belts that falls into a final tray that transports to a container that has the fruit that is not classified in any of the previous sizes, as shown in Figure 5 and Figure 6.

In addition, the machine has an ON/OFF switch on the right side that allows the passage or not of electrical power to the motor.



**Figure 5** Finished machine of the sorter
*Source: Own Elaboration*



**Figure 6** Final view of blueberry sorter
*Source: Own Elaboration*
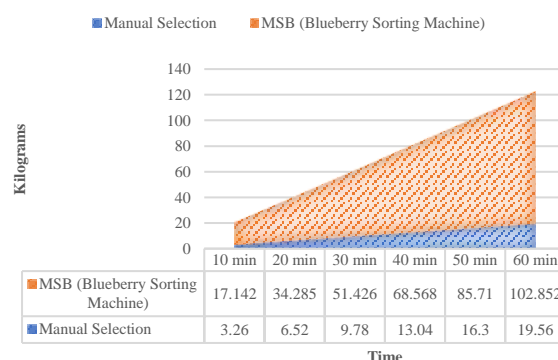
**Scope and limitations of the machine**

Scope:

− It has a belt system that controls the size of the fruit.

− The electrical source is 127 v.

− The machine has 4 types of fruit classification.

− It speeds up the sub-process and preserves the fruit blum.

− The machine is operated by a trained operator May of age.

− There is a user's manual on the use of the sorting machine.

Limitations:

− Users may only have one sub-process of everything involved in the fruit.

− The configuration of the calibration of the belts can only be done by authorized personnel.

− The project does not contemplate the maintenance of the sorting machine.

− The mobility of the machine is carried out by two or more people.

As for its operation, a comparison was made between the selection process of blueberry, the results are shown in Graph 1, in the blue part shows the selection time manually, in this type of selection the time is a little high and the production was approximately 20 kilograms per sorter in about 1 hour, in the orange part shows the graph of the sorting machine in which clearly shows a significant improvement in production times.



| | 10 min | 20 min | 30 min | 40 min | 50 min | 60 min |
|---|---|---|---|---|---|---|
| MSB (Blueberry Sorting Machine) | 17.142 | 34.285 | 51.426 | 68.568 | 85.71 | 102.852 |
| Manual Selection | 3.26 | 6.52 | 9.78 | 13.04 | 16.3 | 19.56 |

**Graph 1** Graph of manual sorting times compared to the sorting machine
*Source: Own Elaboration*

Once their operation was demonstrated, the blueberry sorting machines (Figure 7) were delivered to the community of Xoxonacatla Zacatlán Zacatlán Puebla, Mexico.

**Figure 7** Delivery of the blueberry sorter to growers
*Source: Own Elaboration*

## Acknowledgment

## Conclusions

A study of the blueberry sorting machine was carried out, which showed advantages over manual fruit selection. That is to say, an optimization in the time and movements in the selection of the fruit for later packaging was obtained, which is a benefit to the producers, in addition to protecting the blum of the fruit in this process.

The fruit selection stage is the most important, which is why a system for this process was integrated. Based on the information collected from the blueberry growers, a structural, mechanical-electrical model was designed and then the prototype was manufactured.

Once the tests were successfully completed, the equipment to be delivered to the producers was manufactured in series, and at the same time the manuals for operation, failure and repair of the equipment, as well as user training, were prepared.

## References

Chang, W., Wang, X., Yang, J. y Qin, T. (2023). Un modelo de clasificación mejorado basado en CatBoost para la idoneidad ecológica de los arándanos. Sensores, 23 (4), 1811.

González, R. 2022. Zacatlán abre sus puertas para la fiesta de cosecha de blueberry. Grupo Milenio. Consultado el 18/03/2021. Disponible en https://www.milenio.com/politica/comunidad/concordia-zacatlan-abre-puertas-cosecha-blueberry

INTAGRI. 2016. El Cultivo de Arándano. Serie Frutillas Núm. 17. Artículos Técnicos de INTAGRI. México. 10p. Consultado el 06/04/2023. Disponible en https://www.intagri.com/articulos/frutillas/El-Cultivo-de-Ar%C3%A1ndano-o-Blueberry

Lippi, N., Senger, E., Karhu, S., Mezzetti, B., Cianciabella, M., Denoyes, B.,... & Chiara, M. (2023). Desarrollo y Validación de un Léxico Multilingüe como Herramienta Clave para los Análisis Sensoriales y Pruebas de Consumidor de Frutos de Arándano y Frambuesa. Agricultura, 13 (2), 314.

Rudas, C. A., 2015. Diseño de un sistema mecatrónico para la selección de arándanos, Tesis para optar al grado de Magíster en Ingeniería Mecatrónica, Pontificia Universidad Católica del Perú, Consultado el 04/04/2023. Disponible en http://hdl.handle.net/20.500.12390/270

Shimabukuro R. T. 2020. Diseño de un sistema de visión por computadora para la clasificación de arándanos por tamaño y características asociadas al color. Tesis para obtener el título profesional de Ingeniero Mecatrónico, Pontificia Universidad Católica del Perú. Consultado el 04/04/2023. Disponible en https://tesis.pucp.edu.pe/repositorio/handle/20.500.12404/17062

Zorenc Z, Veberic R, Slatnar A, Koron D, Miosic S, et al. 2017. Un arándano silvestre 'albino' (Vaccinium myrtillus L.) de Eslovenia muestra tres cuellos de botella en la vía de las antocianinas y diferencias significativas en la expresión de varios genes reguladores en comparación con el tipo de baya azul común. PLOS ONE 12(12): e0190246. https://doi.org/10.1371/journal.pone.0190246