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Characterization of the Quality of the Apple (Malus Domestica) 2024 Harvest of ITSSNP for Database

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ABSTRACT
This document shows the results of the characterization of the Malus domestica apple variety corresponding to the 2024 harvest of the National Technological Institute of Mexico / Higher Technological Institute of the Sierra Norte of Puebla (ITSSNP). At this institution, a limited but representative quantity of apples belonging to a variety native to the Zacatlán region, Puebla, Mexico, is cultivated. Currently, this production, although representative of the region, lacked studies on its physicochemical properties and a defined approach for its utilization. The objective was to generate a reliable database through an experimental analysis with random fruit collection, evaluating variables such as Brix degrees, acidity percentage, and texture. The results allowed for the identification of key indicators of maturity and quality, useful for classification, standardization, and industrial processes. Ripening showed an increase in sugars and a decrease in acidity, reaching an optimal balance for consumption and industrialization. In particular, Malus domestica grown at ITSSNP reached 18° Brix and 1.15% acidity, values that reflect a sweet fruit with low acidity and potential for the fresh market as well as for the production of juices and mild ciders.
Keywords **-** Physicochemical Apple, Properties, Utilization.

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I. INTRODUCTION

Fruit production is a key activity in the agro-industrial sector, with a significant impact on the economic and social development of producing regions according to the Food and Agriculture Organization of the United Nations (FAO), (2019).

At the Technological Institute of the Sierra Norte of Puebla, a limited but representative amount of apples is grown, belonging to a variety native to the region of Zacatlán, Puebla, Mexico. Currently, this production lacks a defined approach for its utilization, as well as specific studies that support its inclusion in productive projects. There is also no documented information on its physicochemical properties, such as texture, acidity, and sugar content. Therefore, the objective of this study is to conduct a detailed analysis of the collected fruits, evaluating tree by tree, in order to obtain representative averages and establish a database that serves as a basis for decision-making and the formulation of productive and industrial projects that generate added value to production.

The apples grown at ITSSNP are presented as an agricultural resource of great interest. However, their full utilization requires a detailed knowledge of their physicochemical properties. This can be achieved through a systematic approach to sampling, analysis, and data management, according to Montgomery, D. C. (2020).

Vázquez-Cuecuecha, O; et al; in (2023) are consulted since they conducted a study on the physical and chemical characterization of the fruits of the apple varieties Prunus persica and Batsch in Tlaxcala. The research design was experimental. For the physicochemical analysis, weight, pH, °Brix, acidity, firmness, among others, are taken into account; the methodology included three main phases: 1) fruit collection, 2) physical and chemical measurements, and 3) statistical analysis. The study highlights post-harvest indicators useful for both the industry and local producers.

Marmolejo-Basurto is studied, in (2023), for his study on physicochemical characteristics and sensory evaluation of pasteurized mixed drinks, sweet potato-apple and sweet potato-pineapple; the drinks were evaluated for pH, acidity, soluble solids, browning index, turbidity, color, and enzymatic activity; the thermal treatment applied achieved the inactivation of the enzyme pectinmethylesterase, with the sensory test showing high acceptability in both drinks. The effect of genetics and climate on the sugar and organic acid profiles of the apple was analyzed by Bourne et al. (2023).

Ayora Brito, J. L; in 2024 investigated the extraction and characterization of pectin from apple (Malus domestica Royal Gala) using the acidic hydrolysis method. The study, experimental in nature with a 2^3 factorial design, evaluated the effects of temperature, time, and pH on the yield of pectin, which was subsequently characterized physicochemically. The methodology consisted of three phases: 1) preparation of the raw material, 2) extraction by acid hydrolysis, and 3) physicochemical characterization; it highlights the use of local raw material, the application of a replicable and low-cost process; however, the study is limited to a single variety and geographic area, which reduces the possibility of generalizing its results at the national level.

Pérez-Portillo, E; et al, in 2024, study the coating of yellow apples (Malus domestica) of the Golden Delicious variety: Carnauba wax and candelilla wax versus chitin-chitosan biopolymers. They conducted an experimental investigation with a comparative design; physicochemical and sensory variables were evaluated over 18 days at three temperatures. The phases they carried out are: 1) Coating formulation, 2) Application to apples, 3) Shelf-life evaluation, 4) Sensory test with 100 judges. The Q-Qn coating allowed extending the shelf life up to 8 days longer than the control. The use of orange essential oil (OEO) had negative effects at 35 °C.

The research by Oviedo G. C.P. (2024) is consulted, who determined the phenology and evaluated the fruit quality of the apple varieties Agua Nueva, Rayada, Fuji, and Gala. The results showed that the Gala variety reached 15.70 °Brix and 4.64% titratable acidity; the Fuji variety presented 13.35 °Brix and 6.36% acidity; while the Agua Nueva variety obtained 16.88 °Brix and 3.22% acidity. The study was carried out in two orchards located in Jicolapa, Zacatlán, Puebla, Mexico.

Pérez, et al. (2025) characterized seven varieties of Malus domestica Borkh., evaluating parameters such as weight, color, firmness, soluble solids, pH, acidity, ripeness ratio, and agro-industrial potential. The results highlighted Winter Banana for its high soluble solids content and low firmness, Dorset Golden for its elevated pH values and ripeness ratio, and Anna and Pennsylvania for their higher acidity and size, respectively. Overall, Dorset Golden and Winter Banana are identified as having the best physicochemical characteristics for industrialization in Colombia.

II. METHODOLOGY

For the study, a representative sample composed of five Malus domestica trees was selected, considering criteria of uniformity and location within the cultivation area on July 30, 2024. The collection and distribution of the specimens are presented in Figure 1.

Figure 1. Collection and distribution of apple trees.

For a quick and accurate analysis of the apple, a refractometer is used using a °Brix of sucrose dissolved in 100 grams of solution. For the determination of the °Brix degrees, the refractive index method was used, in this case a handheld refractometer, ATAGO brand, as shown in figure 2.

Figure 2. Refractometer used to carry out the tests for the determination of °Brix degrees

Regarding the percentage of acidity, this varies according to the variety of apple, the growing conditions, and the degree of ripeness, constituting a key parameter in industrial processing, as it influences the flavor, preservation, and standardization of products such as juices and concentrates.

For the determination of the percentage of acidity, the direct volumetric method was used, employing 0.1 N sodium hydroxide, phenolphthalein as an indicator, and distilled water. It should be noted that the results are reported as a percentage of citric acid, in accordance with the regulations established for soft drinks and fruit-derived beverages. In Figure 3 we can observe the laboratory where the acidity tests were carried out.

Figure 3. Acidity tests and volumetric determination carried out in the Multipurpose Laboratory of the ITSSNP.

For the evaluation of the texture, the simple compression methodology was used, employing a needle device as a measuring instrument. This procedure allowed obtaining precise data on the apple's resistance to the application of a controlled force. See figure 4.

Figure 4. TAXT Texture Equipment and the needle device used for the determination of texture in this specific case of the apple (Malus domestica)

III. RESULTS

The first test was carried out on July 30, 2024. Each analysis was performed in triplicate for the purpose of ensuring data reliability and obtaining representative results. See Table 1.

Table 1. Physicochemical Analysis 01 (07/30/2024)

Árbol	Fuerza Mínima Kg	Fuerza Máxima (kg Fuerza)	Adhesión (kg fuerza)	Tiempo Mínimo (s)	Tiempo Máximo (s)	°Brix
1	0.0962	0.5305	-0.1621	0.125	2.497	8
2	0.0933	0.4924	-0.1534	0.188	2.497	10
3	0.1199	0.5373	-0.1898	0.08	2.496	9
4	0.0647	0.477	-0.129	0.145	2.492	15
5	0.1107	0.643	-0.191	0.16	2.495	11
6	0.0994	0.544	-0.1584	0.17	2.399	10
7	0.1141	0.405	-0.1098	0.46	2.498	14
8	0.1197	0.5978	-0.1762	0.17	2.489	11
9	0.0837	0.4741	-0.1235	0.162	2.499	11
10	0.086	0.6422	-0.1552	0.14	2.499	13
Promedio	0.09877	0.53433	-0.15484	0.18	2.4861	11.2

In texture analysis, when talking about minimum force and maximum force, it is referring to the amount of force (generally in Newtons or gram-force) that the instrument applies and that the sample offers as resistance during the test.

The minimum force refers to the first measurement recorded at the beginning of the test, right at the moment when the probe or compressor of the texturometer comes into contact with the surface of the fruit. This parameter indicates the amount of force needed to break the skin or start its deformation. In the case of apples, a low minimum force value is usually associated with a softer skin or a higher degree of ripeness of the fruit.

Maximum force corresponds to the peak resistance presented by the sample during the test, just before its internal structure breaks. This parameter reflects the maximum firmness of the fruit, which is directly related to the compactness of the pulp and the integrity of its cells. In the case of apples, a high maximum force value indicates greater firmness, a characteristic typical of fresh and crunchy fruits.

The interpretation of the results indicates that a low minimum force is associated with smoother skin, a characteristic that generally reflects a higher degree of ripeness in the fruit. Similarly, a low maximum force corresponds to less firm pulp and lower crunchiness, which can influence the perceived quality of the fruit during its consumption or processing.

The graph in Figure 5 shows the minimum penetration resistance recorded in the apple samples, expressed in kilogram-force (kgf). The analysis

yielded an average value of 0.1 kgf, which constitutes a relevant indicator of the fruit's texture and firmness, properties closely related to its degree of ripeness and postharvest quality. The graph indicates the penetration resistance of the apple samples expressed in kilogram-force (kgf). An average value of 0.1 kgf was obtained in the measurement conducted on July 30, 2024, corresponding to the fruit texture analysis.

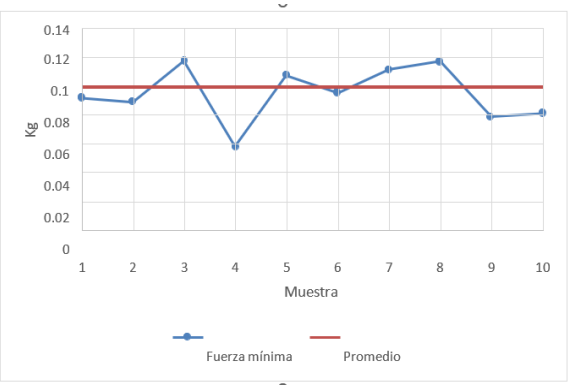

Figure 5. Minimum strength test

The graph in Figure 6 shows the maximum penetration resistance of the apple samples, expressed in kilogram-force (kgf). An average value of 0.55 kgf was obtained, which reflects the level of firmness of the fruit during the measurement.

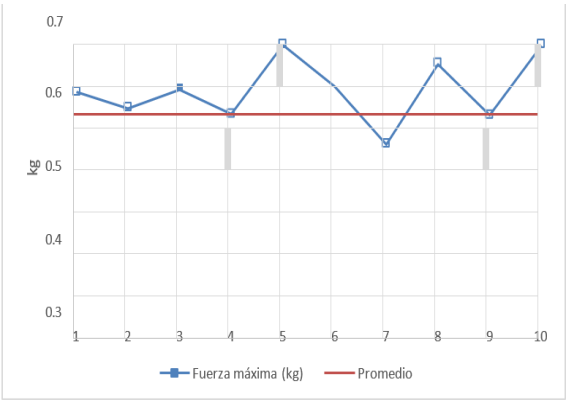

Figure 6. Maximum strength test.

In the texture test, adhesion strength refers to the amount of force needed to separate two surfaces that have been in contact, generally the food and the texture analyzer probe. In the case of the apple, this parameter is associated with stickiness or the tendency of the surface to adhere, and it is measured when the probe penetrates the fruit and is then withdrawn, recording the negative (tensile) force required to detach it. A high adhesion strength value indicates that the surface is stickier or that the pulp tends to adhere more intensely to the instrument, while a low value reflects little to no stickiness; see figure 7.

In practical analyses, the adhesion strength in fresh fruits is usually low, since their surface does not present stickiness; however, this value can increase when the apple is overripe, has been processed into puree, or is coated with sticky substances, such as syrup or glaze. In the graph in Figure 7, the adhesion strength of the apple samples is observed, obtaining an average value of –0.15 kgf.

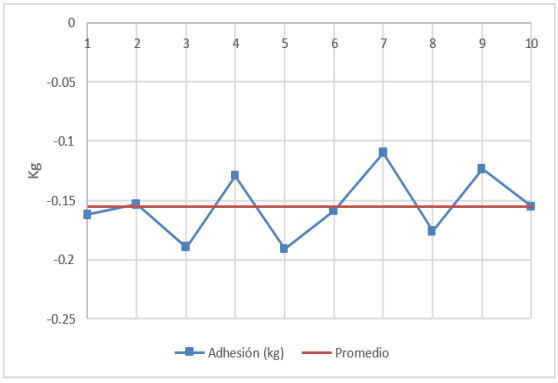

Figure 7. Adhesion test

The minimum time corresponds to the moment when the instrument detects the first contact with the fruit and begins to record resistance, marking the beginning of deformation or penetration. This parameter can be related to the smoothness of the skin or to the speed at which the pulp yields, that is, the moment when the fruit begins to "be felt." In contrast, the maximum time refers to the point at which the fruit completely yields, corresponding to the moment when the equipment records the highest resistance of the sample or the rupture of its internal structure. It generally coincides with the peak force in the graph and indicates the limit up to which the apple maintains its firmness before breaking or deforming completely.

Refer to figure 8 where the representation of the minimum penetration time of the needle in the apple is shown.

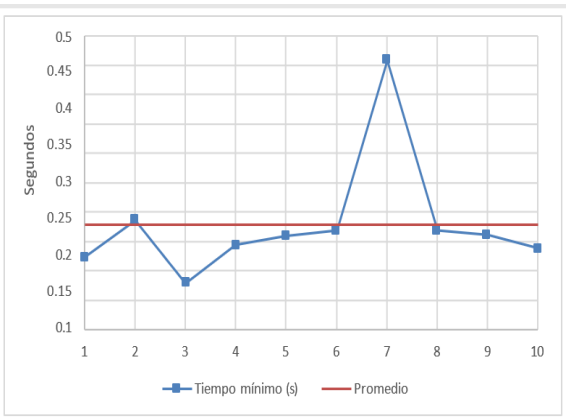

Figure 8. Minimum time test

The representation of the maximum penetration time of the needle in the apple is shown in Figure 9.

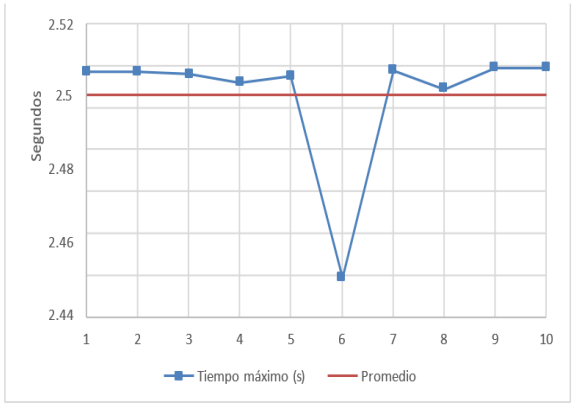

Figure 9. Maximum time test

The evaluated Malus domestica apple reached 15° Brix, indicating an adequate content of total soluble solids, mainly sugars. This value reflects a level of sweetness considered optimal for fresh consumption and competitive for industrial processing, as it is associated with good organoleptic quality and market acceptance of the fruit. The results are shown in Figure 10.

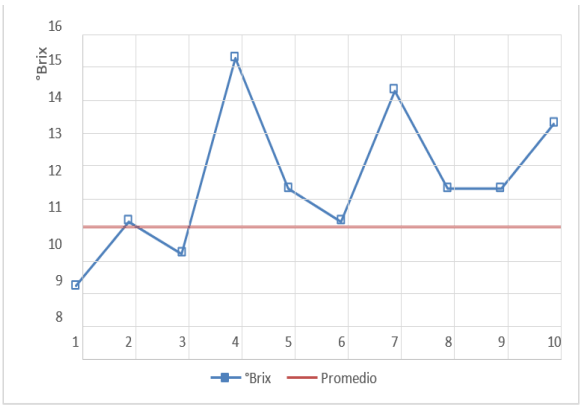

Figure 10. °Brix test on the apple.

Table 2. Determination of acidity with an average of 0.81%

Muestra	Volumen Inicial	Volumen Final	Normalidad	%Acidez
M_1	45.8ml	47.3	0.1N	0.96
M_2	47.4	48.4	0.1N	0.64
M_3	48.4	49.4	0.1N	0.64
M_4	49.6	51.4	0.1N	1.15
M_5	51.4	52.8	0.1N	0.84
M_6	53	53.8	0.1N	0.51
M_7	53.8	54.6	0.1N	0.51
M_8	54.6	56	0.1N	0.89
M_9	56	57.8	0.1N	1.15
M_{10}	57.8	59.2	0.1N	0.89

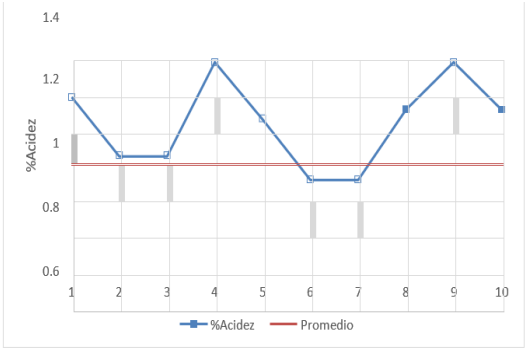

Figure 11. Percentage of acidity of the sample taken on July 30, 2024

Test 02 was carried out on August 8, 2024 and was carried out with the purpose of obtaining reliable results. Table 3 presents the values obtained.

Table 3. Physicochemical analyses conducted on August 8, 2024

Árbol	Manzana	Fuerza mínima (kg fuerza)	Fuerza máxima (kg fuerza)	Adhesión (kg fuerza)	Tiempo mínimo (s)	Tiempo máximo (s)	°Brix
1	1	0.0879	0.5531	-0.1681	0.11	2.482	10
1	2	0.1718	0.6853	-0.1541	0.195	2.5	11
2	1	0.1188	0.4961	-0.1524	0.215	2.47	11
2	2	0.1013	0.5458	-0.1804	0.203	2.47	16
3	1	0.1022	0.497	-0.1358	0.21	2.5	15
3	2	0.0607	0.4794	-0.1444	0.068	2.425	16
4	1	0.1026	0.4954	-0.1444	0.185	2.502	12
4	2	0.0695	0.4472	-0.1312	0.105	2.507	11
5	1	0.395	0.4462	-0.0958	0.113	2.5	16
5	2	0.0892	0.4845	-0.1222	0.125	2.5	15
6	1	0.1061	0.5317	-0.1717	0.177	2.502	15
6	2	0.0701	0.4957	-0.151	0.098	2.475	15
7	1	0.0975	0.5425	-0.1743	0.077	2.502	14
7	2	0.0601	0.4515	-0.1414	0.09	2.462	15
8	1	0.0869	0.519	-0.2	0.09	2.49	14
8	2	0.1232	0.5869	-0.1538	0.19	2.467	14

Test 03 was carried out on August 20, 2024. In Table 4, the values found can be observed.

Table 4. Physicochemical analyses carried out on August 20, 2024

Árbol	Manzana	Fuerza mínima (kg)	Fuerza máxima (kg)	Adhesión (kg)	Tiempo mínimo (s)	Tiempo máximo (s)	°Brix
1	1	0.0879	0.5531	-0.1681	0.11	2.482	12
1	2	0.1718	0.6853	-0.1541	0.195	2.5	13
2	1	0.1188	0.4961	-0.1524	0.215	2.47	13
2	2	0.1013	0.5458	-0.1804	0.203	2.47	18
3	1	0.1022	0.497	-0.1358	0.21	2.5	17
3	2	0.0607	0.4794	-0.1444	0.068	2.425	18
4	1	0.1026	0.4954	-0.1444	0.185	2.502	14
4	2	0.0695	0.4472	-0.1312	0.105	2.507	13
5	1	0.395	0.4462	-0.0958	0.113	2.5	16
5	2	0.0892	0.4845	-0.1222	0.125	2.5	17
6	1	0.1061	0.5317	-0.1717	0.177	2.502	17
6	2	0.0701	0.4957	-0.151	0.098	2.475	17

Discusion

When consulting the proposal by Vázquez-Cuecuecha, O. et al. (2023), it is detected that the difference with our research lies in the fact that this study applies advanced statistical tools, such as Principal Component Analysis (PCA) and Pearson correlations, while our work focuses on the characterization of texture, the determination of acidity, and the content of soluble solids expressed in °Brix degrees.

The study conducted by Ayora Brito, J. L. (2024), is oriented toward the obtaining of functional additives such as pectin, whereas our study focuses on the characterization of texture, the determination of acidity percentage, and the analysis of soluble solids in °Brix of the evaluated samples.

In the proposal presented by Pérez-Portillo, E. et al. (2024), they compare biopolymers and waxes under variable environmental conditions, whereas our study focuses on the quantitative and experimental characterization of the Zacatlán apple (Malus domestica), through the determination of texture, acidity, and soluble solids expressed in °Brix.

On the other hand, Marmolejo-Basurto (2023) conducted a sensory evaluation of beverages formulated with sweet potato–apple and sweet potato–pineapple blends, unlike our research, in which only apple (Malus domestica) was used.

The study by Pérez et al. (2025) was compared, who reported that the Dorset Golden and Winter Banana varieties exhibited the best physicochemical characteristics in Colombia with 13° Brix and 0.4% acidity, while the Malus domestica variety evaluated in Zacatlán, Puebla, Mexico, proved to be more suitable for industrial processing, with 15° to 18° Brix and 1.15% acidity, reflecting a higher sugar content and moderate acidity favorable for industrial processes and consumption.

The study by Oviedo G. C. P. (2024) reported 15.70 °Brix for the Gala variety, similar in sweetness to the ITSSNP apple, but with 4.64% titratable acidity, which makes it more acidic than the ITSSNP sample. The Fuji variety reached 13.35 °Brix, being less sweet, but had a high acidity of 6.36%. On the other hand, the Agua Nueva variety obtained 16.88 °Brix, being sweeter and with moderate acidity of 3.22%. This indicates that, in general, the apples from Oviedo's study have more acidic profiles compared to those from the ITSSNP.

IV.CONCLUSION

The ripening of the apple showed an increase in sugars and a decrease in acidity, reaching an optimal balance point for consumption and industrialization. In the case of the Malus domestica apple grown at ITSSNP, 18° Brix and 1.15% acidity were obtained, values that reflect a sweet fruit, with a low level of acidity and favorable characteristics

both for the fresh market and for the production of juices and mild ciders.

REFERENCES

[1] Ayora Brito, J. L. (2024). Extraction and characterization of pectin from apple (Malus Domestica Royal Gala), using the acid hydrolysis method [Engineering thesis, University of Cuenca]. UCuenca Institutional Repository. https://dspace.ucuenca.edu.ec/handle/123456789/43936

[2] Bourne, P., et al. (2023). Effect of Genetics and Climate on Apple Sugars and Organic Acids Profiles. Agronomy, 12(4), 827.)

[3] Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction. Rome: FAO; Retrieved from https://www.fao.org

[4] Food and Agriculture Organization of the United Nations (FAO). (2024). World Food and Agriculture – Statistical Yearbook. Rome: FAO https://www.fao.org

[5] Marmolejo-Basurto, E. K. P; Ochoa-Martínez; González-Herrera, S. M and Gallegos-Infante J. A. (2023). Physicochemical characteristics and sensory evaluation of mixed sweet potato-apple and sweet potato-pineapple beverages. Journal of Science and Technology. Tecnociencia Chihuahua. National Technological Institute of Mexico/ IT of Durango, Division of Graduate Studies and Research. Durango, Mexico. Pp 1-13.

[6] Montgomery, D. C. (2020). Design and analysis of experiments (10th ed.). Hoboken, NJ: John Wiley & Sons.

[7] Oviedo G. C.P. (2024). Determination of the phenology and evaluation of the fruit quality of the apple from Zacatlán, Puebla. National Autonomous University of Mexico. Faculty of Higher Studies Iztacala, Tlalnepantla, State of Mexico. Pp. 1-77

[8] Pérez, C., Deaquiz, Y., Silva, A., Cely, G., and Almanza, P. (2025). Physicochemical characterization of seven apple (Malus domestica Borkh) varieties established in the high tropics. Journal of Agrarian and Environmental Research, 16(1), 357 - 376. https://doi.org/10.22490/21456453.8141

[9] Pérez-Portillo, E; García-Gómez, R.S; Mendoza-Pérez, S; Duran-Domínguez-de-Bazúa, M. C. (2024) Coatings for yellow apples (Malus domestica) of the Golden Delicious variety: Carnauba wax and candelilla wax versus chitin-chitosan biopolymers. Ambiens Techné Et Scientia México, 12(2), 179-209. https://atsmexico.org/atsm/article/view/186

[10] Vázquez-Cuecuecha, O., García-Gallegos, E., & Chávez-Gómez, J. A. (2023) Physical and chemical characterization of the fruits of three varieties of Prunus persica L. Batsch in Tlaxcala. Mexican Journal of Agricultural Sciences, 14(5), 86–95. https://doi.org/10.29312/remexca.v14i5.3197