Vinegar elaboration from cherry fruit discard (*Prunus cerasus* L.)

Elaboración de vinagre a partir de frutos de cerezas (*Prunus cerasus* L.) de descarte

Elaboração de vinagre a partir de cerejas descartadas (*Prunus cerasus* L.)

Nelson Loyola Lopez*
Sergio Lagos Marambio
Carlos Acuña Carrasco
Mariela Arriola Herrera

Departamento de Ciencias Agrarias. Facultad de Ciencias Agrarias y Forestales. Universidad Católica del Maule, 684, Carmen, Curicó, Chile.

Rev. Fac. Agron. (LUZ). 2023, 40(4): e234034
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v40.n4.03

Received: 30-07-2023
Accepted: 16-10-2023
Published: 10-11-2023

Food Technology
Associate editor: Dra. Gretty R. Ettiene Rojas
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Keywords:
Substitute
Fermentation
Acetic acidity

Abstract

The production of vinegar from the fermentation of cherry (*Prunus cerasus* L.) discard was experimentally evaluated. Four treatments were used: filtered vinegar, unfiltered vinegar, pasteurized vinegar and vinegar with metabisulfite. The physicochemical and organoleptic characteristics and their acceptability were determined through a completely randomized experimental design with three (3) repetitions per treatment. The data were analyzed according to an analysis of variance, with a 95 % confidence level to determine possible significant differences between the treatments. The parameters were measured; soluble solids, density, pH, sodium chloride and acidity. Also, a sensory analysis of the attributes was carried out; color, aroma, texture and flavor, with 33 trained panelists, in order to evaluate the organoleptic characteristics and acceptance of each of the samples. The cherry vinegar prepared and evaluated after 5, 20 and 35 days did not show significant differences in its physicochemical characteristics. The panelists perceived more differences in sensory attributes when the vinegar was pasteurized according to the treatment (T_2). The panelists did not vary their perception of the acceptability of vinegar, regardless of the treatment applied.

*Corresponding author: nloyola@ucm.cl

Resumen

Se evaluó experimentalmente la elaboración de vinagre proveniente del fermentado del descarte de cerezas (*Prunus cerasus* L.). Se
emplearon cuatro tratamientos: vinagre filtrado, vinagre no filtrado, vinagre pasteurizado y vinagre con metabisulfito. Se determinaron las características fisicoquímicas, organolépticas y su aceptabilidad mediante un diseño experimental completamente al azar con tres (3) repeticiones por tratamiento. Los datos se analizaron según un análisis de varianza, con un 95 % de confianza para determinar posibles diferencias significativas entre los tratamientos. Se midieron los parámetros; solidos solubles, densidad, pH, cloruro de sodio y acidez. También, se realizó un análisis sensorial de los atributos: color, aroma, textura y sabor, con 33 panelistas entrenados, con la finalidad de evaluar las características organolépticas y la aceptación de cada una de las muestras. El vinagre de cerezas elaborado y evaluado a los 5, 20 y 35 días no mostró diferencias significativas en sus características fisicoquímicas. Los panelistas percibieron más diferencias en los atributos sensoriales, cuando se pasteurizó el vinagre según el tratamiento (T_2). Los panelistas no variaron su percepción de la aceptabilidad del vinagre, independiente del tratamiento aplicado.

Palabras clave: sustituto, fermentación, ácido acético.

Resumo

A produção de vinagre a partir da fermentação de resíduos de cereja (*Prunus cerasus* L.) foi avaliada experimentalmente. Foram utilizados
quatro tratamentos: vinagre filtrado, vinagre não filtrado, vinagre pasteurizado e vinagre com metabissulfito. As características físico-químicas e organolépticas e sua aceitabilidade foram determinadas através de delineamento experimental inteiramente casualizado com três (3) repetições por tratamento. Os dados foram analisados segundo análise de variância, com nível de confiança de 95 % para determinar possíveis diferenças significativas entre os tratamentos. Os parâmetros foram medidos; sólidos solúveis, densidade, pH, cloreto de sódio e acidez. Além disso, foi realizada uma análise sensorial dos atributos; cor, aroma, textura e sabor, com 33 provadores treinados, a fim de avaliar as características organolépticas e aceitação de cada uma das amostras. O vinagre de cereja elaborado e avaliado após 5, 20 e 35 dias não apresentou diferenças significativas nas suas características físico-químicas. Os provadores perceberam mais diferenças nos atributos sensoriais quando o vinagre foi pasteurizado de acordo com o tratamento (T_2). Os painelistas não variaram na percepção da aceitabilidade do vinagre, independentemente do tratamento aplicado.

Palavras-chave: substituto, fermentação, acidez acética.

Introduction

The word vinegar comes from Latin, "vinum acre", which means sour wine. The alcohol that is present in the liquid is acetified by aceto bacteria and hence its chracteristically sour flavour. It is favorable in preparing foods for those demanding palates of the XXI century (Mazza and Murooka, 2009).

Vinegar is used as an additive for many foods, especially the Gourmet ones. It tracends due to the presence of metabisulfite of sodium ($Na_2S_2O_5$) in vinegar, it gives antioxidants and antiseptic power (Acuña, 2013). It has increased its production, being statistically calculated that during 2014; 6,618,500 L of vinegar coming from forestry - agricultural sector were imported worldwide. Among the varieties demanded are artichokes, pickles, grapes, malt, rice, apples, olives (ODEPA, 2015).

Cherries belong to the Rosaceae family, two great varieties are found (*Prunus avium* L.), which are sweet and (*Prunus cerasus* L.) which are bittersweet, they are also known as sour cherries. These two varieties are forerunners of the rest of the improved subvarieties for their overcrowding and production. Cherries have many properties, they are, rich in fibers, they have a high level of Vitamins A and C; another factor is the presence of anthocyanins and flavonoids, giving the food a great antioxidant- anticancer potencial to the consumer (Magri *et al*., 2023). In this investigation, the species *P. cerasus*. var "Bing" was used. It comes from the North of India and the Caspian Sea. It has been found wild in Macedonia, Asia Minor and in Caucasus.

This current research allows generating an added value to the cherries that can not be traded in a fresh state. Cherry vinegar elaboration could be performed by small and médium producers so as to facilitate the market demands and it generates family employment; a process technically easy to elaborate, visually attractive and acceptable.

The general objective was to assess the vinegar elaboration coming from cherry discard of fresh consumption and its chemical and sensorial contribution.

Materials and methods

Cherries were obtained from Santa Elba Farm in the Province of Curico- Chile (Latitude 35° 2´4.79" S, Longitude 71° 21´53.17" 0). The fruit corresponded to the species *Prunus cerasus* "Bing" variety. This consisted with a physiological degree of over-maturation, not being optimal for exportation in fresh state. A five- liter container was used, with a solution at 2 % of NaClO in order to desinfectate three kg of cherries coming from the discard process. They came from a freezing state at – 18 °C to inhibit any type of biological action after they were classified as discard fruit. The weights of the cherries were controlled twice in order to measure, in proportions, the quantity of juice resulting from this process.

Several procedures were performed to obtain the vinegar (figure 1).

Physicochemical analysis

The physicochemical reactions of the product considering these aspects: soluble solids (°Brix), density (g. mL^{-1}), pH (values), NaCl ($g.L^{-1}$) and acidity (%) (table 1).

To Sodium chloride**,** the procedure was based on the following formulae:

$$\% \text{ NaCl} = \frac{\text{mL consumed x 0.1 N x 0.05845 x 100 x 10}}{\text{10 mL of the sample}} \quad (1)$$

To acidity, the procedure was based on the following formulae:

$$\% \text{ ACIDITY} = \frac{\text{V x N x F x 100}}{\text{M}} \quad (2)$$

Where: V: volume spent of NaOH, N: normality of NaOH, F: predominant acidity factor (Acetic acid = 0.060), M: sample (g).

.

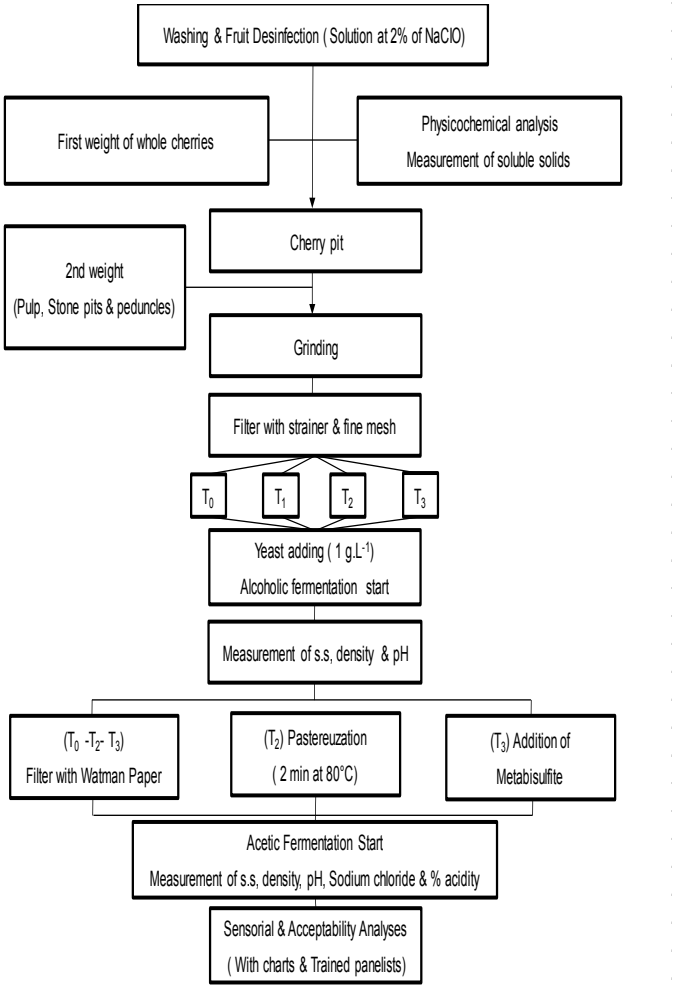

Figure 1. Flow of vinegar elaboration process by using Cherry discard.
Source: Acuña, 2013.

Table 1. Methods used for determining the chemical components.

Components	Methods & sources
Soluble solids	Official Refractometer Method of Analysis AOAC 932.12 Soluble Solids in fruits. (1980).
Density	Quercus Lab. (2010). How to use a densimeter.
pH	Hanna Instruments. (2005). Operating Manual H18424 pHmeters.
Sodium chloride	Chávez Cury, G. (2006).
Acidity	Official Method Official of Analysis AOAC 942.15 acidity (assessable) in fruit products, (2000).

The content of soluble solids, density, pH, sodium chloride and acidity were quantified. The first analysis was performed at day 5, at the acetification point, the second and third analyses were carried out at day 20 and day 35, respectively. All the analyses were made in triplicate.

Preparation on vinegar from cherry fruit

It consisted in detaching the pits of each fruit. Considering that the weight of the peduncles and stone pits meant 8% of the total sample, they were eliminated together with the 32% of the filtered pulp with skin. Grinding was performed by using a mixer and then the whole content was filtered by using a finer mesh than the previous one.

The juice volume resulting from the cherry discard was fractioned according to the relation of 0.6 $L.kg^{-1}$ of raw material and it was divided into four equal packages of 1000 mL, to homologate the elaboration conditions and then 50 mL of each treatment were taken. In order to transform the sugar coming from the raw material into alcohol, yeasts were used, such as, *Saccharomyces cerevisiae*- Fermivin ® PDM N° 8906 according to the relation of 1 $g.L^{-1}$. The optimal temperature for them to act is at 18° C (Acuña, 2013). For the acetic fermentation and vinegar obtained it was used the methodology according to Hernández and Barbero (2008).

The mixtures were homogenized by shaking and 40 $mg.L^{-1}$ of metabisulfite at 60 % of purity were added (Minagri, 2023). The vinegar was poured into a clean cotainer, and then, it was submerged in water within another container at a temperature of 80 °C for two minutes and; thus, giving origen to treatment (T_2).

Organoleptic and accceptability analyses

Thirty-three trained panelists assessed the intensity of the sensorial attributes of cherry vinegar in the four treatments with non- structured charts and with structured charts to measured acceptability.

Experimental design

The experimental unit in this study corresponded to 1.8 L of vinegar. The experimetal design corresponded to a completely at random design. Thus, for evaluating the results the R Development Core Team (2010) were used. A normality analysis was carried out with the Shapiro- Wilk Test. When the former followed a Normal Law (p- value < 0.05), the results were analysed with ANOVA; with Tukey test at 5 % of significance (HSD). The elaborated vinegar was performed by using four different treatments with three treatments (table 2).

Table 2. Description of the elaborated treatments for producing vinegar.

Treatments			
T_0	T_1	T_2	T_3
Filtered vinegar	Non-filtered vinegar	Pasteurized vinegar	Vinegar with metabisulfite

In relation to the sensorial analysis, the answers were arranged in tables; they were subjected to non- parametric variable analyses with Kruskal- Wallis Test.

Results and discussion

Physicochemical Analyses: The analysis of normality showed that there were no significant differences among the different treatments to elaborate cherry vinegar (Table 3) and by the existence of a small sample size (n), this analysis was approached in a descriptive way.

Soluble solids

The content of soluble solids (°Brix) obtained before analysing the elaborated vinegar with the respective treatments did not show statistically verifiable differences (data are not shown). The content of soluble solids in all the elaborated vinegars stayed within the ranges between [5.3 – 5.9 °Brix] with the respective treatments, both, at the beginning of the acetic fermentation (day 5), as the sensorial assessment (day 35).

Table 3. Physicochemical analyses record for each treatment.

Component	T_0				T_1				T_2				T_3			
	5	20	35	Standard deviation	5	20	35	Standard deviation	5	20	35	Standard deviation	5	20	35	Standard deviation
S.S (°Brix)	5.90	5.70	5.90	4.76	5.80	5.50	5.30	4.52	5.50	5.50	5.90	4.61	5.8	5.9	5.7	**4,74**
Density ($g.mL^{-1}$)	10.18	10.22	10.36	8.37	10.18	10.27	10.36	8.39	10.17	10.2	10.37	8.37	10.18	10.24	10.38	**8,38**
pH (Values)	3.72	4.21	4.20	3.31	3.98	3.89	4.07	3.25	3.85	4.02	3.93	3.21	3.56	4.24	3.9	**3,20**
Sodium chloride ($g.L^{-1}$)	0.12	0.38	0.53	0.35	0.12	0.20	0.23	0.16	0.06	0.15	0.29	0.18	0.09	0.15	0.18	**0,12**
Acidity (%)	1.62	1.68	1.69	1.36	1.47	1.43	1.36	1.16	1.67	1.69	1.71	1.38	2.35	2.79	2.41	**2,07**

According to Reyes and Hernández (2016), the existing °Brix quantity depended exclusively of the natural concentration of sugars from the raw material. In this case, the fact that all the treatmnents were carried outwith an initial juice of 17.8 °Brix confirmed what was stated by the authors. The initial soluble solids and those existing in cherry vinegar diminished approximately in 12.2 °Brix due to the fermentation process. Part of the sugars were transformed into alcohol and later on, in acetic acid as it was stated by Zapata *et al*. (2019). The filtered vinegar (T_0) showed a slight increase at day 35 in relation to the rest of the vinegars and their treatments because, the acetic colonies were extracted to it and it was not subjected to any physicochemical process.

Density

The density in the vinegar elaborated for this study did not show any statistically significant differences (data are not shown). It was observed that the vinegars elaborated with treatment T_2 (pasteurized vinegar) diminished in the assessment at day 20, in relation to the other elaborated vinegars with the other treatments. According to Casale *et al*. (2006), the fact that temperatures vary drastically, they would produce changes in the evolution of the product; thus, having submitted only this treatment to a pasteurized process at 80° C during two minutes, would be the explanation of the difference. In all the treatment the density of the vinegar increased at day 35 of its elaboration.

pH

The values of pH obtained after analysing the vinegar elaborated with their respective treatments did not show statistically significant differences (data are not shown). At day 20, the environment, where vinegar microorganisms were acting, was altered so as to differentiate the treatments with pasteurization (T_2) and the addition of metasufite (T_3). This provoked slight changes in the pH means (0.11 and 0.14, respectively), in relation to the highest value of the records of vinegar elaboration with the other treatments. According to FAO (2015), when metabisulfie is used in very low quantities, it inhibits enzymatic browning, and it prevents fungi development. This, together with any important fluctuating situations of temperatures, enzymes are inactivated, and they impede the homoeostatic stage, which alter pH. Based on what it was expresed by the authors, it was confirmed that independent of the treatment applied, significant differences in pH in the elaborated vinegar were not observed.

Sodium chloride

The values of sodium chloride that were obtained after analysing the elaborated vinegar in their respective treatments did not show statistically verifiable differences (data are not shown). The content of sodium chlroride in all the treatments where it was applied was less than 1 chloride $g.L^{-1}$ (Minagri, 2023). The values of sodium chloride of vinegars obtained that were further from the limit of the norm [$X < 1\ g.L^{-1}$], were those where metasulfite was added (T_3), precisely, when it was assessed at day 20 with $0.15\ g.L^{-1}$. The closest value exceeded this with a 66%, corresponding to (T_0) at day 35; but both did not significantly affect the required value of sodium chloride requested by the Chilean Norm and they were within the requested norm for elaborating vinegars in Chile (Minagri, 2023).

Acidity

The values of acidity obtained after analysing the vinegar did not show significant differences (data are not shown); eventhough, in the second measurement corresponding at day 20, post onset of the acetic fermentation, those vinegars that had treatment (T_3) obtained the highest percentage (2.79) of acetic acid under study. According to the Norm Codex- STAN- 162-1995, point 8.1.3 in the labelling, the total content of acetic acid must be expressed in percentage (minimum 4 % in 100 mL to 20 °C) plus, the name of the food and rounded up to the nearest whole number. Therefore, this value would be nominated as 3 % of acidity in cherry vinegar.

Unlike the norm, which is based on acidification, records from the raw material having high ranges of soluble solids, the maximum obtention of acetic acid in this product is closely related to the initial content of soluble solids of cherries. Moreover, it is necessary to highlight that such elaboration constitutes an innovation within vinegars; whereby, an extension or amplification by part of the supervisory body, in question, is proposed in oder to regulate it before a possible commercialization.

Analysis of the organoleptic attributes

The attributes of cherry vinegar were perceived by the panelists as moderately red colours, a slightly strong aroma, with semi- transparent texture and a sour flavour. When the panelists assessed the sensorial attributes of the elaborated vinegars, using the four treatments, they perceived them with different intensity.

Color

The results obtained from the perception of the color attribute, by some panelists, did not show a normal distribution; thus, Kruskal-Wallis test was performed which evidenced significant differences in the treatments applied to the elaborated vinegar (figure 2).

Values obtained with equal letters differ statiscally with 95 % of reliability, Kruskall-Wallis.

Color faithfully represented the tonality of the raw material in question, according to the panelits comments expressed in the charts. Particularly, the vinegar obtained from the non-filtered treatment (T_1), got perception values with significant differences in relation to those elaborated with treatments (T_0 and T_2), in as much as the non-filtered one which was more concentrated. According to Meléndez-Martínez *et al*. (2004), color becomes a quality index, and it indicates the optimum degree or deterioration of the product.

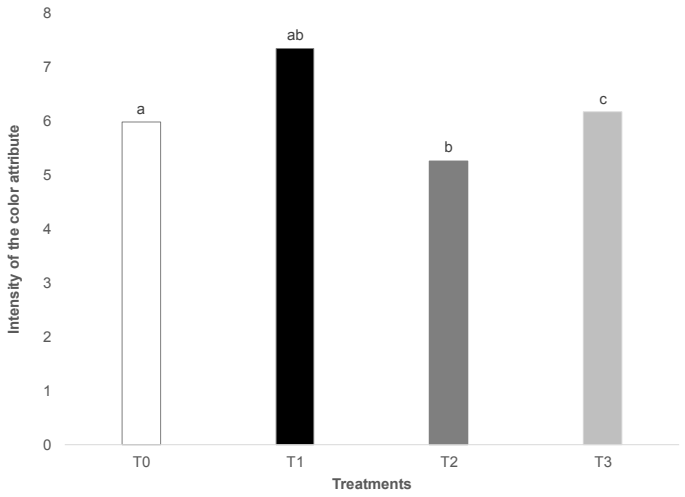

Figure 2. Average values of the color attribute in the different treatments.

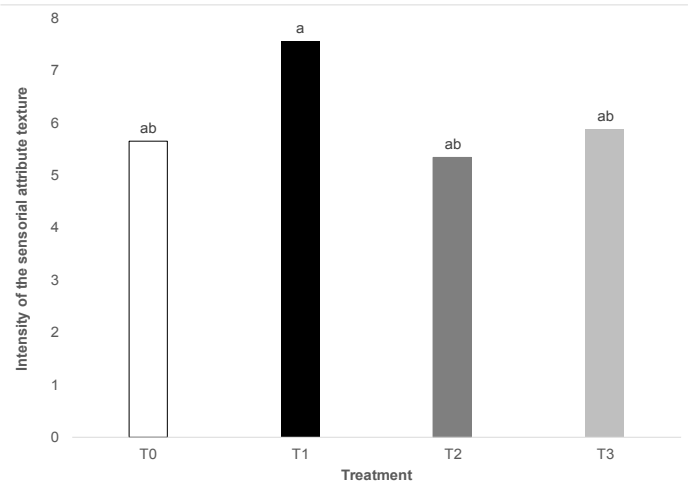

Figure 3. Average values of the texture attribute in the different treatments.

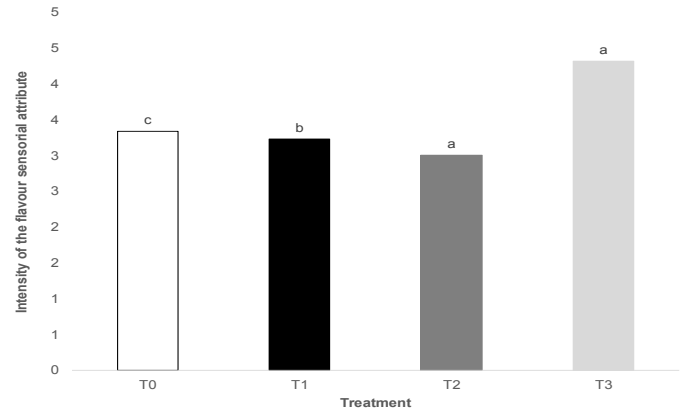

Figure 4. Average values of the flavour attribute in the different treatments.

Aroma

The assessments of the sensorial attibute aroma performed by the trained panelits showed a normal distribution; thus, Tukey test was performed with a reliability of 95 %. The former showed significat differences, independently of the applied treatment (Data are not shown). As far as the average punctuation of the aroma perceived in the vinegars using the four treatments ranged between 6.42 and 6.91. This attribute was assessed with less perception of the study, and it was statistically justified, where there were not significant differences among the obtained results.

Texture

The results obtained from the perception of the texture attribute showed a normal distribution; thus, the Tukey test was applied with a reliability of 95 %, showing significant differences among the applied treatments of the elaborated vinegar (figure 3).

Obtained values with equal letters differ statistically at 95 % reliability, Tukey.

In relation to the cherry vinegar texture, the panelits perceived the samples of treatment T_1 with a 7.56 mark. It was very different from the other three treatments, as filtered treatment (T_0), pasteurized treatment (T_2) and treatment with Metabisulfite (T_3), which were assessed with a punctiation range of 5.6. This was statistically proven.

Flavour

The results obtaned from the perception of the flavour sensorial attribute did not show a normal distribution; thus, the Kruskall- Wallis test was applied. It demonstrated significant differences in the four treatments applied (figure 4).

Values obtained from equal letters differ statistically with a reliability of 95 %, Kruskall-Wallis.

The vinegar elaborated with treatment T_3 (vinegar with metasulfite); the flavour attribute was perceived as stronger than the one elaborated with treatment T_2. The last treatment was subjected to high temperatures, thus, generating that the aromatic compounds were volatilized, they changed their polarity, and they changed their concentration level (Vera-Loor *et al*., 2020) and probably may cause less acceptability for the panelists. Another aspect that was observed was that the treatment where metasulfite was added (T_3), cherry vinegar obtained a higher average rating (4.32). While the vinegars with the treatments T_0 and T_1 showed similar average ratings [3.34 and 3.24] by part of the panelits.

A Good storage is essential for preserving these organoleptic attributes over time, because the indiscriminated presence of oxygen produces the precipitation of harmful insoluble substances for the quality of the product (Casale *et al*., 2006).

Acceptability analysis

The resulting values of the elaborated vinegar acceptability measurements did not show a normal distribution, thus, Kruskal-Wallis test was performed. By using the statistical test with a reliability of 95 %, it showed that there were no significant differences in the acceptability attribute, idependetly of the applied treatment (Values are not shown). In relation to the acceptability results, significant differences were not appreciated among treatments, eventhough, 50% of the panelits did not dislike the product ("I slightly dislike it"). Meanwhile, the treatment using metasulfite (T_3) reached the highest average punctuation (3.4) and the lowest punctuation was for the vinegar elaborated with filtered treatment (T_0), with an average of 2.6, no significant differences were found among these vinegars.

Conclusions

The hypothesis was partially approved because it was feasible to elaborate vinegar from cherries with chemical valoration, despite the statiscal differences in the sensorial attributes; color, texture, and

flavor by using the different treatments, preserving the original aroma of the cherries and an acceptability with a value of 3.05; indicating that "they slightly disliked it".

In relation to the soluble solids, density, pH, sodium chloride and acidity of elaborated cherry vinegars did not statistically vary with each of the treatments.

Panelist perceived differences in the color of vinegar because of the treatments, from high lightening the reddish color to the semi-transparent color as well as in the taste of the vinegar. Therefore, panelist did not perceive difference in the sensorial attribute aroma with a score from 6.42 to 6.91, which quickly generated the acknoledgement of the raw material.

Literature cited

Acuña, C. (2013). Personal interview with the autor about vinegar elaboration. Acuña was chemical technician at the Maule Catholic University. https://maule.ent.sirsidynix.net/client/es_CL/default/search/results?ln=es_CL&q=acuña

Casale, M., Sáiz-Abajo, M. J., González-Sáiz, J. M., Pizarro C., & Forina, M. (2006). Study of aging and oxidation processes of vinegar simples from different origins during storage by near-infrared spectroscopy. *Analytica Chimica Acta, 557* (1-2), 360-366. https://doi.org/10.1016/j.aca.2005.10.063

Chávez Cury, G. (2006). Revisión experimental del intervalo de pH para la determinación de cloruros por el método de Mohr. *Revista Boliviana Química, 23* (1), 24–26. http://www.scielo.org.bo/scielo.php?script=sci_arttext&pid=S0250-54602006000100005

Hernández, I., & Barbero, F. 2008. Bacterias acéticas: técnicas de detección y eliminación. https://docplayer.es/7226243-Bacterias-aceticas-tecnicas-de-deteccion-y-eliminacion.html

Magri, A. Malorni, L. Cozzolino, R. Adiletta, G. Siano, F. Picariello, G. Cice, D. Capriolo, G. Nunziata, A. Di Matteo, M., & Petriccione, M. (2023). Agronomic, Physicochemical, Aromatic and Sensory Characterization of Four Sweet Cherry Accessions of the Campania Region. *Plants, 12*(3) 2-22. https://doi.org/10.3390/plants12030610

Mazza, S., & Murooka, Y. (2009). Vinegars Through the Ages. In: Solieri, L., Giudici, P. (eds) Vinegars of the World. Springer, Milán (pp. 18-19). https://doi.org/10.1007/978-88-470-0866-3_2

Meléndez-Martínez, A. J., Vicario, I. M., & Heredia, F. J. (2004). Estabilidad de los pigmentos carotenoides en los alimentos. *Archivos Latinoamericanos de Nutrición 54*(2) 209-215. http://ve.scielo.org/scielo.php?script=sci_isoref&pid=S0004-06222004000200011&lng=es&tlng=es

Minagri, Ministerio de Agricultura. (2023). Ley 18.455: producción, elaboración y comercialización de alcoholes etílicos, bebidas alcohólicas y vinagres. https://www.bcn.cl/leychile/navegar?idNorma=29859

Official method of Analysis - AOAC. (1980). Analisis quimicos. Determinación de solidos solubles, según Método Refractométrico Oficial AOAC 932.12 Sólidos solubles en frutas. 13ª edición. Washington, DC. USA. https://archive.org/details/gov.law.aoac.methods.1980/mode/2up?view=theater

Official method of Analysis - AOAC. (2000). Analisis quimicos. Determinación de acidez, AOAC 942.15 acidez (valorable) en productos de frutas. 17ª edición. Washington, DC. USA. https://www.dspace.espol.edu.ec/bitstream/123456789/25528/7/ANEXO%205%20942.15.pdf

Oficina de Estudios y Políticas Agrarias, Odepa - ODEPA. (2015). Frutales: superficie y producción. Consultado el 02 de mayo 2015. https://www.odepa.gob.cl/articulos/MostrarDetalle

Organización de las Naciones Unidas para la Alimentación y la Agricultura - FAO. (1995). Codex Alimentarius. Azúcares, productos del cacao y el chocolate y productos diversos. Segunda edición. Roma, Italia. 216 p https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXS%2B192-1995%252FCXS_192s.pdf

Organización de las Naciones Unidas para la Alimentación y la Agricultura - FAO. (2015). Alimentos sanos y seguros. Consultado el 28 de agosto 2015. http://www.fao.org/docrep/014/am401s/am401s05.pdf

R Development Core Team. (2010). *R:* a language and environment for statiscal computing. Viena: R Foundation for Statical Computing. Consultado el 01 de septiembre 2015. https://www.r-project.org/

Reyes, K., & Hernández, M. (2016). Cuantificación de vinagre obtenido de la cáscara de piña por medio de fermentación alcohólica y acética, y su incidencia en la productividad, en una empresa guatemalteca. *Revista de la Escuela de Estudios de Postgrado, 7*(1), 22-27. ISSN 2518-4725 https://core.ac.uk/reader/228879632

Vera-Loor, J. Cedeño-Palacios N., & Mera-Vélez, S. (2020). Elaboración de vinagre de vino a partir del mucílago y exudado de cacao criollo (*Theobroma cacao* L.). *Revista Científica INGENIAR: Ingeniería, Tecnología e Investigación, 3*(6), 2-13. https://doi.org/10.46296/ig.v3i6.0014

Zapata, I. Ochoa, S. Alzate, A. Zapata, A., & Rojano, B. (2019). Vinegar of andean berries (*Vaccinium meridionale* SW): Antioxidant and antiproliferative activity in colon cancer cells SW480. *Vitae, Revista de la Facultad de Ciencias Farmacéuticas y Alimentarias, 26*(3), 135-147. http://dx.doi.org/10.17533/udea.vitae.v26n3a02