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Effect of sugar substitution by aguamiel on the physicochemical quality of pear jam (*Pyrus communis* L.)

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ABSTRACT
Objective: Analyze the effect of the sugar substitution by dehydrated aguamiel on the physicochemical quality of pear jam (*Pyrus communis* L.).
Design/methodology/approach: Different levels of sugar substitution by dehydrated aguamiel were analyzed (0, 25 and 50%). Physicochemical parameters on pear jam as color, pH, acidity, density, consistency and soluble solids were evaluated.
Results: Results showed that the physicochemical and color characteristics of the pear jam was changed by the substitution of sugar by dehydrated aguamiel.
Study limitations/implications: More studies related to sensorial analysis of the pear jam and technological functions of dehydrated aguamiel are required.
Findings/Conclusions: Pear in advanced stage of maturity could be considered as a good ingredient in jam formulation. Dehydrated aguamiel was used as an alternative sweetener in jam.

Keywords: Aguamiel, pear jam, quality, sweetener

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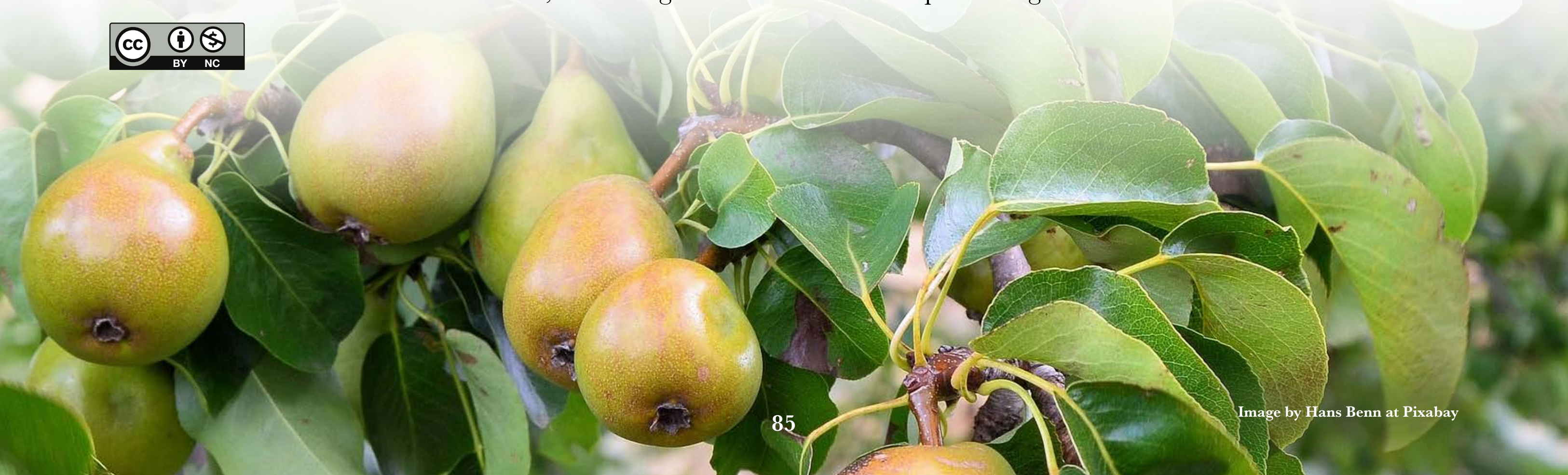
INTRODUCTION

The pear (*Pyrus communis* L.) is a fruit that is native to regions of Eastern Europe, China, Central Asia, Western Asia. It grows in a mild temperate zone and its cultivation is very old; it is classified as a *Pyrus* species of the Rosaceae family of the Rosales group (Kalkisim *et al.*, 2018). China is one of the nations that contributes two thirds of the world pear production, being a little more than 25 million per year (Kalkisim *et al.*, 2018). Mexico produces approximately 26,000 tons of pear annually, where the main producer is the state of Puebla, becoming one of the four main producing nations of the fruit in the American



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continent (SADER, 2020). It is estimated that the edible portion of the pear is 88 g per every 100 g of fresh product (FEN, 2022). Its maturation velocity is very high, so its incorporation in different foods should be promoted. Among the uses of the pear are the production of cider, liqueurs, jams, juices, jellies, preserves, among others (SADER, 2020).

On the other hand, aguamiel is a liquid that is obtained from the Agavaceae family, it has a sweet smell and taste (Ramírez-Cuellar *et al.*, 2018), and it has a translucent and yellowish appearance; its composition is water and sugars of which glucose, fructose and sucrose predominate, it also contains proteins, and mineral salts (Ramírez-Cuellar *et al.*, 2018). Aguamiel has nutritional and physicochemical properties that give it a prebiotic food category (Ramírez-Cuellar *et al.*, 2018), as well as being a source of compounds with antioxidant activity (Romero-López *et al.*, 2015). This liquid has been used as an ingredient in products as drinks (Changoluisa Maigua, 2020) and nectars (Bautista, 2006), but it can be incorporated in products derived from fruits such as jam. Therefore, the aim of this work was analyze the effect of the sugar substitution by dehydrated aguamiel on the physicochemical quality of pear jam.

MATERIALS AND METHODS

Materials. Pear (*Pyrus communis* L.) was obtained from the supply center of the city of Toluca, State of Mexico, Mexico. Aguamiel was obtained from local producers of Texcaltitlan, Estado de México. Sugar (Zulka, Zucarmex, México), water (Bonafont, México), pectin (Aglupectin®, Italy) and citric acid (Fermont, México) were used to jam elaboration. All reagents used were reagent grade.

Physicochemical evaluation of pear and its pulp. Color (Chroma meter CR-41, Konica Minolta), hardness (Model CT3 10, Brookfield), total soluble solids (Máster refractometer, Atago), titratable acidity (Parra *et al.*, 1998), and moisture determination (OHAUS, Model MB-27) were evaluated.

Aguamiel dehydration. Aguamiel was put into an aluminum recipient and was heated at 92 °C during 3 h.

Jam elaboration. 150 mL of water was put in an aluminum recipient, and it was heated at 70 °C, then, pear, sugar, dehydrated aguamiel, pectin and citric acid were added according the formulations of Table 1, and were mixed during 15 min. The jam was cooled at room temperature and was kept in a glass container in refrigeration until its analysis.

Table 1. Formulations of pear jam at different level of sugar substitution by dehydrated aguamiel (DA).

Formulation	Control (0%)	25%	50%
Pear (g)	500	500	500
Sugar* (g)	250	187.5	125
DA (g)	0	78.13	156
Water (mL)	150	150	150
Pectin (g)	8	8	8
Citric acid (g)	3	3	3

*Sugar substitution was according to the sugar content (100%).

Physicochemical analysis of aguamiel. Total soluble solids (Máster refractometer, Atago, Japón), pH (Muñiz *et al.*, 2020), titratable acidity (López. 2017), and color (Chroma meter CR-410, Konica Minolta, Chiyoda, Japón) were evaluated in fresh and dehydrated aguamiel.

Physicochemical analysis of pear jams. Total soluble solids (Máster refractometer, Atago, Japón), pH, density (Elcometer, Gardco Paul N. Gardner Company Inc, USA), consistency (Bostwick Consistometer, CSC Scientific Company, INC, USA), titratable acidity (López. 2017), and color (Chroma meter CR-410, Konica Minolta, Chiyoda, Japón) of pear jams were analyzed.

Analysis of results. The experiments were done in triplicate. MS-Excel 2014 software was used for data analysis.

RESULTS AND DISCUSSION

Physicochemical evaluation of pear and its pulp. Table 2 shows the results of the analyzes carried out on the pear, which were color, hardness, soluble solids, titratable acidity, and moisture.

The color analysis of the evaluated pear residues presented values of L of 29.259, a* of 5.63 and b* of 10.72 with a tendency to black, red, and yellow. This is due to the high state of maturity that it presents, as well as a decrease in chlorophyll and the appearance of carotenoids, where the green color tends to decrease as the state of maturity advances, presenting the yellow color (Poveda, 2015).

The hardness or firmness is an important property in the quality, acceptance of the fruit by consumers and storage (López-Camelo, 2003). This property is a function of the harvest or harvest time and storage temperature, related to the external color of the fruit (López-Camelo, 2003; Infoagro, 2022). The hardness value of the pear residues was 7.98±0.22 N (0.8137 kgf), a value commonly associated with softening due to the state of advanced maturity that they show. The firmness and texture of fruits change due to the hydrolysis of starches and pectin, reduction of their fiber content and cell wall degradation processes (López-Camelo, 2003; Infoagro, 2022). In related studies Moggia *et al.* (2005) reported, for pears, an average of 7.8 kgf of postharvest firmness and 5.3 and 5.7 kgf after one month. Meanwhile, Parra *et al.* (1998), reported an initial firmness value of 13 kgf and a decrease to 7.17 kgf after 14 days.

Soluble solids in fruits are composed of sugars, salts, acids, and other water-soluble compounds that are part of the juice, being sugars and the organic acids present inside the fruit the most abundant, increasing as the maturity stage progresses derived from the hydrolysis of structural polysaccharides such as starch, cell wall pectin, accumulating glucose, fructose and sucrose, so they are related to the firmness and color of the fruit,

Table 2. Characterization of pear and its pulp (*Pyrus communis* L).

Color			Hardness (N)	Soluble Solids %	Titratable Acidity %	Moisture %
L	a	b				
29.259	5.63	10.72	7.98±0.22	11.87±0.06	0.49±0.019	82.92±0.014

being pointed out as quality indicators for consumers in these foods (Kader 1999; Yanes, 2018). The percentage of soluble solids in the pear was 11.87±0.06; this value ranges vary from researcher to researcher. Poveda (2005) reported values of 12.83% at advanced maturity; Parra *et al.* (1998) reported values of 6.04% at the beginning of harvest up to 12.7% as the state of maturity progresses.

The fruits acidity is the result of organic acids and sugar precursors present; it is estimated a general tendency to decrease the acidity during the maturation of various fruits, in addition to the biochemical and sensory importance of organic acids, which lies in the fact that they help in flavor, in a typical relationship between sugars and acids in different fruits (del Pilar Pinzón *et al.*, 2007). The titratable acidity of pear residues was 0.4913±0.019%, which is related to values reported by Chiquillanqui (2014) with 0.48% and Kalkisim *et al.* (2017) from 0.2 to 0.59% depending on the variety of the fruit in the locality; it should be noted that the acidity value is low due to the development of the stage of maturity in which the sugar content increases and the malic acid content tends to decrease.

Finally, the moisture content of the pear was 82.92±0.014%, being water the main component. In related studies, Kadam (1995) indicates a humidity value of 87.7% and Kalkisim *et al.* (2018) reports from 63.51 to 88.25% for pear (*P. communis*). The moisture content in fruits and foods is important since it is related to texture, firmness, as well as conservation and processing processes that contribute to quality and safety (Chuquillanqui, 2014).

Physicochemical characterization of fresh and dehydrated aguamiel. Table 3 shows the results of the physicochemical analysis of aguamiel. A higher soluble solids value of dehydrated (80±0.01) than fresh (10.75±0.35) in aguamiel is observed due to the water evaporation during the heating process. According to Palafox *et al.* (2017), the value of soluble solids in fresh aguamiel from Nanacamilpa, Tlaxcala was 12.1±1.4, thus, the value in this study was lower because, it depends on the place and temporality when it was obtained; and in the case of dehydrated aguamiel it depends on the dehydration process. The pH value of the fresh aguamiel was 6.65, which is according to the NMX-V-022-1972 and to Palafox *et al.* (2017) who indicate a range between 6.6 and 7.5 and a value of 6.0±0.4, respectively; after heating the pH value decreased, probably because of the proton exposition after molecular movement and heating. Acidity value of fresh aguamiel was 0.59±0.01, which was lower than the value of the NMX-V-022-1972 and it value also decreased after heating, probably due to acids degradation. On the other hand, the results of color show a black and red color tendency and a reduction of yellow color, these values are associated with a non-enzymatic darkening or the Maillard and caramelization reactions which happened during heating process.

Table 3. Physicochemical characteristics of fresh and dehydrated aguamiel.

Aguamiel	Soluble solids	pH	Acidity (%)	Color		
				L	a	b
Fresh	10.75±0.35	6.65±0.07	0.59±0.01	60.09±0.60	0.79±0.02	12.14±0.32
Dehydrated	80±0.01	4.77±0.01	0.11±0.01	40.73±0.04	6.98±0.04	5.93±0.04

Physicochemical quality of pear jams. The results of the physicochemical characteristics of the different pear jams with and without aguamiel are shown in Table 4. Regarding the soluble solids for the 0% formulation, the value was 51.5±0.7, for 25% it was 43.25±0.35, and for 50% of 46.25±0.35. These results show that the higher the amount of dehydrated aguamiel, the lower the number of soluble solids in the sample. These results are explained because, despite the aguamiel went through a dehydration process, there is still a quantity of water that interferes with the total soluble solids content of the pear jam.

The pH results of the control formulation (0%) (Table 4), showed a higher value (3.805±0.007) compared to that indicated in the COVENIN Standard, which can range between 3.0-3.3; in the case of the other formulations of 25% and 50%, the pH is higher, this due to the presence of dehydrated aguamiel that has a pH of 4.77 (Table 3) so that the pH increases with respect to the increase in the amount of dehydrated aguamiel in the jam.

The density in the jam is a parameter that relates the mass per unit volume of the product. This parameter varies by the type and amount of ingredients in the formulation; at 0% it showed a value of 1.218±0.003 cm^3/mL while at 25% it was 1.186±0.027 cm^3/mL and at 50% it was 1.189±0.024, in both formulations the density decreased.

The consistency is a parameter that is very commonly evaluated in jams; this parameter is an indicator of the gel formation during the cooking of the ingredients. The results obtained show that the jam had a longer run in the consistometer, 0% (2.75±0.35), 25% (6.25±0.07) and 50% (6.4±0.5), which indicates that as the substitution of dehydrated aguamiel increased, the consistency of the jam decreased. The consistency is related to the density which also decreased; this is explained because sugar has an important technological function in the formation of the gel and its texture in such a way that its decrease negatively affects these properties.

The acidity result was different in the formulation of 50% (0.038±0.077) with respect to the formulation of 0% (0.060±0.004) and 25% (0.060±0.004). Kerstupp (2010), who analyze xoconostle jam (*Opuntia joconostle*), shows an acidity percentage of 0.04%, indicating that the 50% formulation has a result like the one presented in this work.

Finally, Table 5 shows the color results of the jams. The value of L decreases as the sugar decreases, but also as the content of dehydrated aguamiel increases, so the values found are because aguamiel had a very dark hue (Table 4) because of heating to which underwent by caramelization of sugars. The a* parameter was positive in all cases, so

Table 4. Physicochemical characterization of pear jams with sugar substitution by dehydrated aguamiel.

Parameter	0%	25%	50%
% Soluble solids	51.5±0.7	43.25±0.35	46.25±0.35
pH	3.805±0.007	4.265±0.021	4.72±0.05
Density	1.218±0.003	1.186±0.027	1.189±0.024
Consistency	2.75±0.35	6.25±0.07	6.40±0.5
Acidity (%)	0.060±0.004	0.060±0.004	0.038±0.077

Table 5. Color of pear jams with sugar substitution by dehydrated aguamiel.

Parameter	0%	25%	50%
L	37.266±0.054	33.91±0.04	29.766±0.060
a	5.71±0.06	9.446±0.045	8.062±0.048
b	10.468±0.093	10.453±0.028	5.944±0.024

the jams have red tones, these values being higher as the concentrated aguamiel content increases. Finally, regarding the b* values, these were positive, showing a tendency towards yellow, but in this case, as the sugar decreases and the concentrated aguamiel increases, the yellow hue decreases.

In general, it was observed that the color was modified mainly by the addition of dehydrated aguamiel, making it darker and tending to red.

CONCLUSIONS

Physicochemical characterization of the pear and its pulp showed an advanced stage of maturity of the fruit, however it could be considered as a good ingredient in jam formulation. Substitution of sugar by dehydrated aguamiel modified the physicochemical characteristics and color of jam pear, therefore more studies about technological function of dehydrated aguamiel are necessary to considered it as an alternative a sweetener in foods. Also, more studies related to sensorial analysis of the pear jam are necessary to conclude about the characterization of the pear jam.

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