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Research Paper

Alternative sugar substitutes in canned cherries with improved nutritional value suitable for special diet consumers

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Abstract. Cherries in syrup were developed with an improved nutritional profile, which can be a healthier choice for people with special diets by the partial and total replacement of sucrose with less caloric polyols as alternative. The tests performed on Bing cherries were: Witness: sucrose 100%, T1: sucrose-maltitol: 50-50%, T2: sucrose-erythritol-maltitol: 20-30-50%, T3: maltitol-erythritol-mannitol: 55-30-15%. The candied cherries reached a 55°Brix for all formulations, which were colored with erythrosine and amaranth. Cherries were packaged and sterilized. A similar behavior was observed in all formulations, regarding the evolution of Brix, pH and density of syrups. The sucrose replacement with polyols had a significant effect ($\alpha = 0.05$) in reducing shear stress and a_w in the finished product when sucrose was replaced by polyol formulations tested with respect to the witness with 100% sucrose. Color, showed significant differences ($\alpha = 0.05$). The T2 formulation reached higher values of lightness, close to red and yellow, being correlated with the results of sensory evaluation. Sensorily, T2 formulation had greater acceptance than the Witness, with 43% preference. According to Art. 235 of Argentine Food Code (1971), the T1 formulation, can be classified as a "low in sugar" food; T2 formulation, as a "reduced caloric value" and "low in sugar" food; while the T3 formulation, as "reduced caloric value" and "no added sugars".

Keywords: Polyols, canned cherries, reduced caloric value products, reduced sugar foods.

INTRODUCTION

Currently, it is estimated that about 1200 million people worldwide are overweight and 171 million live with diabetes. At this rate, it is estimated that by 2015, there will be 2.3 billion people worldwide overweight and that by 2030 there will be 300 million diabetics reported by Granotec Task Group Technical Team (2009). Since several years, the World Health Organization (WHO) and Pan American Health Organization (PAHO) have been warning about the increasing obesity and diabetes around the planet and in Latin America. The increased consumption of high caloric foods, rich in fat, sugar, sodium, and increasingly sedentary life, have all soared the figures for both conditions, until turning the focus of concern of these organisms as reported Granotec Task

Group Technical Team (2009). As published by Lopez-Garcia (2012), the United Nations Organization (UNO) states that, for the first time in history, non-infectious chronic diseases such as cardiovascular disease, diabetes and cancer pose a greater health burden that infectious diseases, causing 35 million deaths a year around the world.

Cubero et al. (2002) said that due to the growing demand for low-calorie foods that preserve adequate turn sweet flavor, sweeteners are one of the areas of greatest biotechnological impact. Low digestible carbohydrates are those that are poorly digested and absorbed in the small intestine and are partially fermented in the large intestine. In support of this, Grabitske and Slavin (2008) found that fermentation products include various compounds such as short chain fatty acids and gases. As a result, they provide low energy content compared to the fully digestible carbohydrates such as sucrose: about 1 to 3 kcal/g for carbohydrates of low digestibility (CLD) compared to 4 kcal/g of fully digestible ones. Within the low digestibility carbohydrates, polyols are used as alternative sugars such as sucrose. Chemically, they are hydrogenated sugars. The hydrogenated monosaccharides (erythritol, mannitol, sorbitol and xylitol) are absorbed more slowly than glucose. The bonds of hydrogenated disaccharides (isomalt, lactitol and maltitol) and hydrogenated polysaccharides (polyglycitol), are more resistant to digestive enzymes, therefore, they are digested and absorbed more slowly.

According to Fujihara (2009), it is important to emphasize that the right type of carbohydrate in the diet may have an important contribution to the food quality, at the same time influencing the welfare of people. Foods that have a low GI (glycemic index) have been scientifically validated as diabetes and overweight control agents. The low GI diets are healthier and promote satiety better.

Regarding sugars, Edwards (2008) mentioned that existing on the market today are several reduced calorie sweeteners and products. However, obesity problems continue growing worldwide. This paradox is probably due to the fact that, according to market research, consumers are not willing to sacrifice the sweet flavour for less calories. The second point is related to the health and/or safety of artificial sweeteners.

Obesity, a common disorder causing excess mortality due to the development of cardiovascular disease, hypertension, respiratory illness, and diabetes, is difficult to control by simple dieting techniques. Low calorie foods, which can facilitate newer weight reduction approaches such as behavior modification, often lack adequate palatability due to the absence of carbohydrate or fat.

Beereboom and Glicksman (2009) said that, while the polyols have many desirable attributes, as sucrose replacements, their utilization caloric values generally prevent a significant caloric reduction when they are used in foods.

Finally, García-Almeida (2013) explained that all non-caloric sweeteners approved for use have been determined to be safe, within permissible levels of consumption. The estimate of intake is difficult to assess, also taking into account that food products in most cases will contain a mixture of them, which further hinders their estimation.

Sugar alcohols and non-nutritive sweeteners are safe when consumed within the daily intake levels established by FDA (Food and Drugs Administration) and ADA (American Diabetes Association) (2008).

According to Edwards (2002), the most common ingredients in foods for diabetics are polyols, since these substances are only slowly absorbed and an increase in the blood glucose levels is avoided. There are also individuals who, due to metabolic problems, cannot consume sucrose.

As said Cubero et al. (2002), the functionality of the polyols in the food industry lies in the following features: relatively low intensity of sweetness, contribution reduced calorie, improved texture given. Some of them are hygroscopic and moisturizing, so they delay the hardening by dryness in some products. A feeling of freshness in the mouth is given if consumed in solid form, they are very little or non cariogenic, control the crystallization of sugars, prevent water evaporation, solubilize flavoring powders and help to rehydrate them, sequester metals, due to their effect on the osmotic pressure, act as preservatives. Polyols have a different chemical composition from sugars, so they behave differently to these, either in food processes or in the body.

Additional support for the advantages over the sugar, comes from the same paper of Cubero et al. (2002) who noted that, added as sugar substitutes in food, they prevents sticking. This is because they absorb water from the environment in a different manner to sugar. By reducing water activity, they can help extend the life of the product where they are applied because they are an obstacle to the growth of bacteria and yeast. They are generally stable to heat treatments, and they have cryoprotective effect.

In agreement with Livesey (2003) and Derache (1990), Grabitske and Slavin (2008) found that the hydrogenated monosaccharides (erythritol, mannitol, sorbitol and xylitol) are absorbed more slowly than glucose. The linkages of the hydrogenated disaccharide (isomalt, lactitol and maltitol) and hydrogenated polysaccharides (polyglycitol) are more resistant to human digestive enzymes than those in sucrose and lactose, and, thus, are digested and absorbed more slowly.

Additional support to understand comes from the work of Livesey (2003), which explains that this property results from the hindrance to digestion and absorption by the alcohol group that replaces the carbonyl group and the ocurrence of other saccharides linkages. Thus, a low

digestibility and/or slow hepatic glucose release is the determinant of their low glycemic and insulinaemic response properties.

According to Derache (1990), these polyols may have laxative effect in high doses, and have established a dose limiting their use, because due to escape intestinal absorption, they are fermented by colonic flora with gas production and organic acids, which determines slight acidification and increases the moisture content and volume colon, favoring increased microbial activity and intestinal peristalsis, even though at low doses, such treatment did not cause problems in cherries.

These polyols are used in diabetics at doses of 30 to 80 g per day in diet containing reduced carbohydrate ratio. Because of the laxative action of these polyols, consumption is performed in split doses.

During the time that polyols reside in the mouth, they resist fermentation and acidogenesis by micro-organisms of dental plaque and are not absorbed via the stomach to any significant degree. Absorption that occurs is by passive diffusion of monosaccharide polyol along a concentration gradient. Disaccharides and higher polyols are too large to difusse from the intestine to the circulation in amounts of more than 2% of oral intake. Some di-, oligo- and polysaccharide polyols may liberate glucose, but as their digestion is slow and incomplete, this does not result in a substantial rise in blood glucose. Likewise, Livesey (2003) states that once absorbed monosaccharides polyols are renally excreted via the kidneys, oxidized directly or converted to glycogen or glucose in the liver; the route of metabolism and excretion depends on their structure. Unabsorbed carbohydrate from polyols is generally fermented completely by the colonic microflora.

Currently, the challenge is to develop products that have certain nutritional claims but also improve health.

MATERIALS AND METHODS

A multiple impregnation process was used by the slower method. This involves placing the fruit in a solution of relatively low initial concentration, which was increased gradually until reaching the desired final concentration, leaving a 24-h period between each concentration increase.

An amount of 3 kg cherry was used, and the sweetener solution is added to them in sufficient quantity to cover all the benefits (ratio of 1: 1.2 solid-liquid).

The process began with an initial sweetener solution with a nominal soluble solids concentration of 25°Brix in order to prevent wrinkling of the fruit. The prepared syrup was boiled and held for 5 min, then was placed cherries and washed and again kept boiling for 5 min. Syrup over the cherries set at rest for a period of 24 h until the next impregnation. At this period, withdrawals sample and corresponding measurements were made. This process was repeated successively, with the purpose of rise the soluble solids concentration in a nominal amount of 10°Brix at each new impregnation, and it was repeated until the sweetener solution reached a minimum concentration of 55°Brix. Five impregnations were carried out in full. The syrup mass was kept constant until the last impregnation. The soluble solids Increase of the syrup in each of the impregnations was determined by mass balance. The experiment was carried out with cherries, Bing variety, 2.2 cm caliber, 3 kg assays were performed in triplicate with the following sample treatments: Witness: 100% sucrose, T1: sucrose 50% - maltitol 50% , T2: sucrose 20% - erythritol 30% - maltitol 50%, T3: 55 % maltitol - 30% erythritol - 15% mannitol. The candying was done in five stages from 25° to 65°Brix. Coloration was done between the third and fourth impregnation with erythrosin and amaranth to 0.0238 and 0.019% respectively and 2% citric acid, reaching pH 3.5. Cherries were packaged in glass flasks of 360 cc and they were autoclaved at 121°C for 10 min using a high-pressure steam esterilizer. The following parameters were measured in triplicate: density (gravimetric and volume), pH (potentiometer Orion M230 A.), T°C, soluble solids (A.O.A.C. 969.38) solutions and pulp during the process, water activity (a_w) with a hygrometer dew point (AquaLab model series 4 TE), shear strength was measured with multipurpose texturometer by using cell Kramer Blade 10 with a load of 5.9 N, and color was measured with Konica Minolta colorimeter CR-400, illuminant D65, for the parameters (L*, a* and b*).

Sampling for syrup and pulp

Three sample portions from different parts of syrup, which was mixed to obtain a homogenate system, were taken. The measurement was performed in triplicate and the mean was calculated.

Measurements in the pulp were carried out on three cherries (replicates) from different parts of the system, following the same steps above. The three separate samples were allowed to stand for 2 min on absorbent paper to remove syrup in excess, then they were crushed and only one portion of liquid was obtained in order to measure the Brix value. The measurements were carried out in triplicate and the mean was calculated. The sampling frequency after each impregnation was:

i) Every 15 min during the first two hours.
ii) Every 1 h between 2^{nd} and 6^{th} hours.
iii) At 24 h.
iv) 48 h after the last (fifth) impregnation.

Sampling for color, texture and water activity

A sample of cherries of each replicates of each treatment

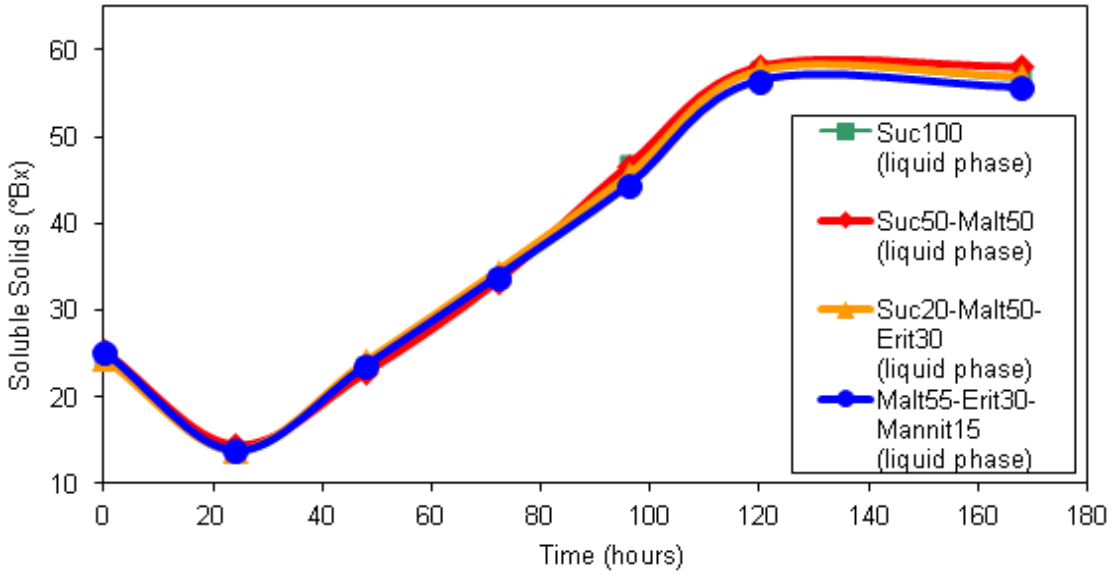

Figure 1. Variation of soluble solids (°Brix) in the syrup as a function of time for the different treatments.

was taken. Measurements were performed in triplicate and the mean was calculated. The sampling frequency was as follows: before the first impregnation, at 24 h of each impregnation and at 48 h for the fifth impregnation, which determined measurements samples at 24, 48, 72, 96, 120 and 168 h.

Sensory analysis

In agreement with Anzaldúa-Morales (1994), two types of tests were used for sensory evaluation: A structured 5-point hedonic scale and a preference test. The finished products were analyzed by 44 randomly selected judges, including not consumers, eventual consumers and consumers of this fruit; aged 24 to 66 years, with a mean of 40 years, 18 men and 26 women. As previously described for Meilgaard et al. (1999), tests were used to evaluate acceptance of the product with respect to the attributes of aroma, flavour, texture and overall acceptance.

Nutritional analysis

The theoretical calculation of calorific value was performed. To calculate energy intakes, nutritional analysis Witness (Suc100) was performed to start from there making theoretical calculations of energy and nutritional values changes for each formulation. The sample consisted of 250 g, representative of tests conducted with the treatment Suc100% was taken and were determined according to AOAC; 1990: Humidity (964.22), Protein Kjeldahl Method (928.08), Total fat, Soxhlet Method (960.39), Ash (940.26), Fiber (992.16) and Carbohydrates (by difference). These determinations were carried out in the Laboratory of the Directorate of Monitoring, Control and Consumer Protection and the Regional Center Mendoza. The sugar content was estimated by difference between total carbohydrate content in product and the total carbohydrates in a cherry, sample before sweetening. By this procedure it was determined that the cherry sample before candying has a value of 0.2 g carbohydrates/100 g.

From these values, the energy and sugar values from other treatments, according to the formulae sucrose replacement values used for each treatment, were determined. All data were statistically analyzed by Centurion StatGraphics XVI.I.

RESULTS AND DISCUSSION

There was a similar physicochemical behavior in all treatments. The overall soluble solids variation in the sweetener solution was plotted against time, with measurements every 24 h after each impregnation, up to 168 h as shown in Figure 1.

In the sweetener solution (syrup) an initial decrease was observed in concentration from syrup 25°Brix added firstly, since it started from a lower concentration to 1°Brix inside the fruit, then the system was recovered with the addition of the second syrup, and thereafter the concentration increased to the last added (the 5th impregnation) at 120 h when it was stabilized. Values close to 55°Brix were reached, where the system almost reached equilibrium values of osmotic pressures. Figure 2 shows what occurred inside cherries, where can be seen a further increase in concentration in the first impregnation, increasing the concentration to 94% and

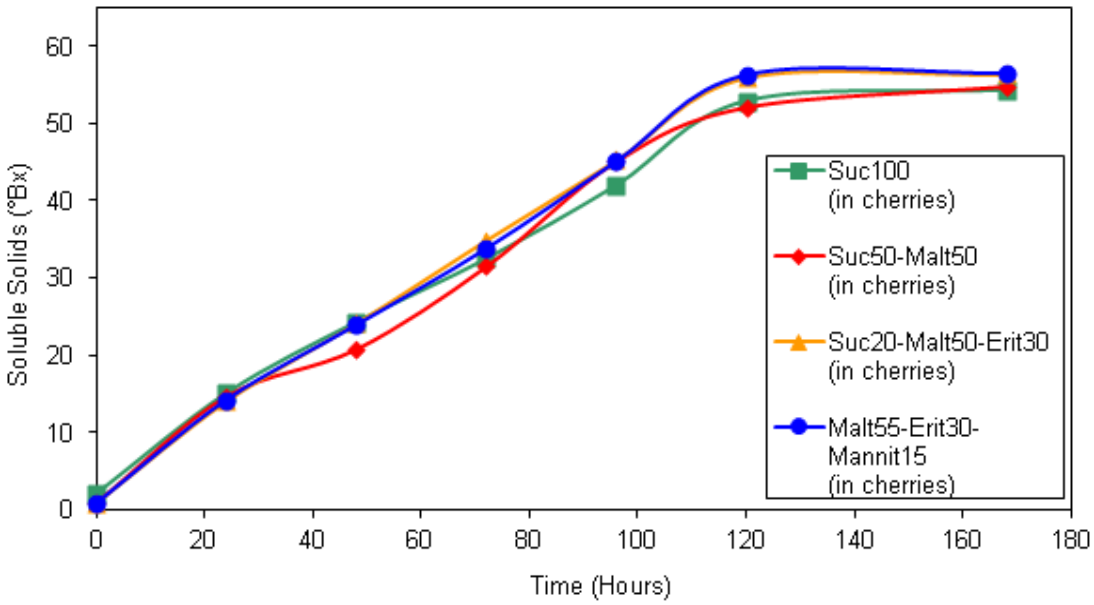

Figure 2. Cherry soluble solids variation (°Brix) in function of time during the confit process to the different treatments.

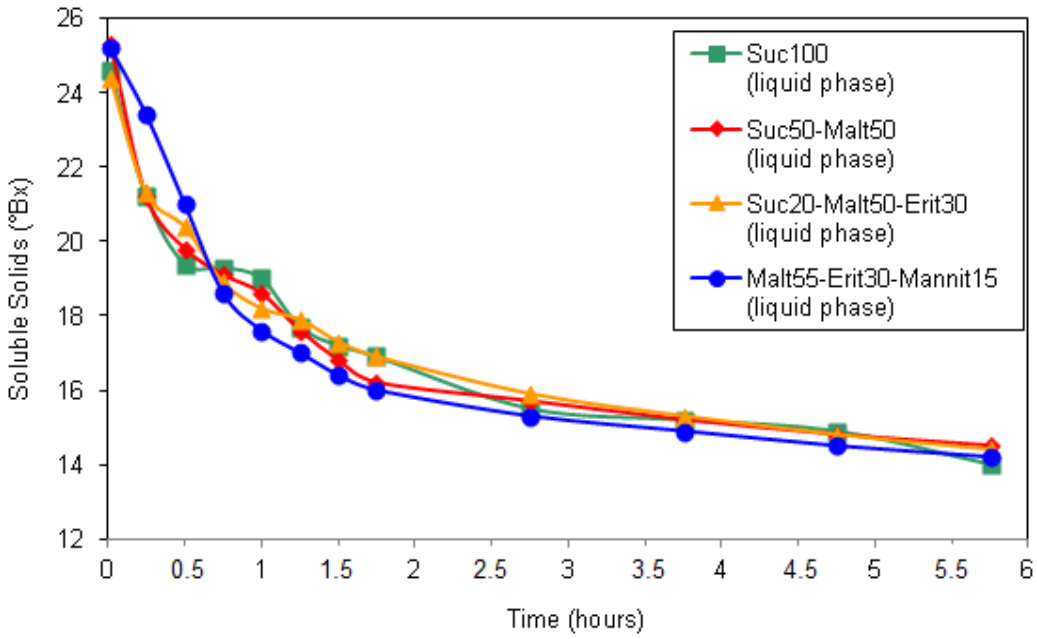

Figure 3. Variation of the concentration of soluble solids (°Brix) of the sweetener solution (liquid phase) in contact with cherries. versus time for the different treatments.

after the final impregnation, increase ranging from 13 to 20%.

Figures 3 and 4 show that the solids exchange rate tended to decrease gradually up to a kinetic equilibrium in which neither solute nor water transfer was shown, and wherein the maximum concentration of soluble solids in the fruit was reached. In all cases, the solution behavior responded to a potential equation y = ax - b and the fruit behavior responded to a logarithmic equation y = a ln (x) + b with high setting values (Table 1). In general, approximately 80% of the variation of soluble solids content of the fruit pulp occurred in the first 4 h of contact between the fruit and the sweetener. There was a higher gain of total soluble solids, represented by Brix pulp grades during the first 4 h, indicating that the rate of concentration was more pronounced in the range

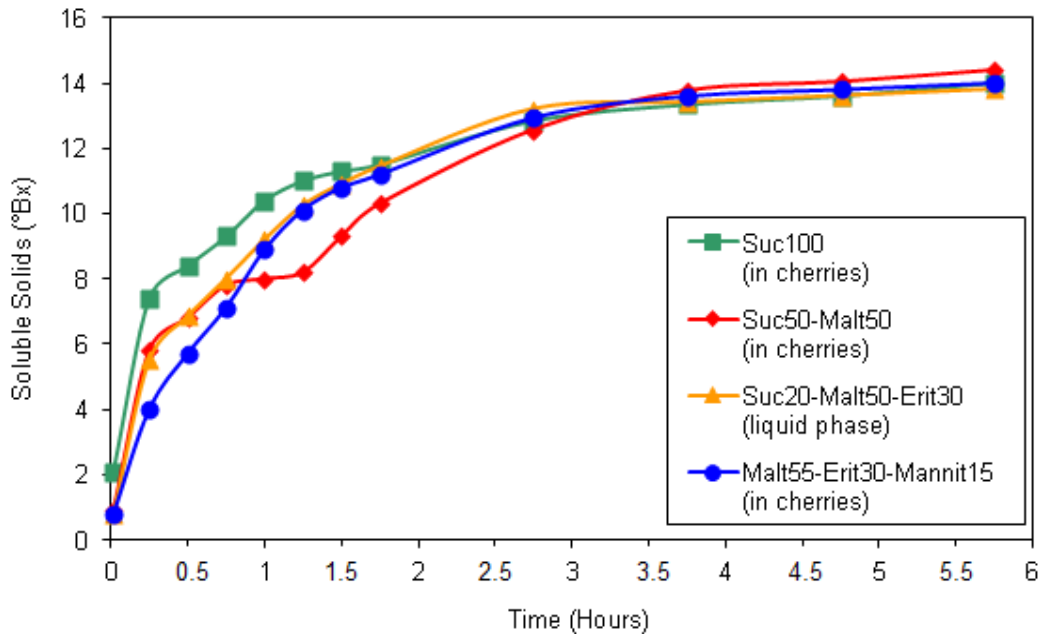

Figure 4. Variation of the concentration of soluble solids (°Brix) in the flesh (solid phase) in contact with the sweetener solution (liquid phase) versus time for the different treatments.

between the first three and first five hours of the process, which is consistent with the findings and results of Pérez et al. (2005) and with the study by Chan (2005). Although this phenomenon was more marked in the first impregnation, it could be observed until the fifth impregnation.

In general, it is observed that as the value soluble solids is increased, more dispersed curves are obtained, and a slight decrease in the settings (R^2) of mathematical models based on this variable is observed.

Figure 5 shows that sucrose was the agent with the lower osmodehydration ability, which according to Azoubel et al. (2000) may be explained by the fact that the sucrose allows the formation of a sub-surface layer of sugar which interferes with the concentration gradients through the sweetening agent-fruit interface, acting as a physical barrier to the removal of water from the fruit. Likewise, Bensouissi et al. (2007) reported that the sucrose crystal surface is rough and it seems that some particles are hidden under a thin layer of sucrose. This was consistent with the values found in the reduction of a_w, which decreased to 16.4% maximum at 168 h: for T2 with a value of a_w of 0.8567. The Witness reached 0.8984; T1, 0.8871; and T3, 0.8584. The treatments with polyalcohols achieved as much greater reduction than the rest. The four treatments showed significant difference among themselves for α = 0.05 and multiple range test according to Fisher test. In agreement with Gontard et al. (1993), this result confirms what we stated above, that the blends using polyols have greater hygroscopic effect than sucrose by taking into account polymer–water interactions which could affect the state of water in food, such as the formation of supplementary hydrogen linkages between water and the polymeric food matrix. The decrease in water activity (a_w) was related to the increased concentration of solids through a polynomial function $y = - ax^2 + bx + c$, with high correlation coefficients too. As for density, the syrup played an important role from the sensory point of view, since a higher density or viscosity gives consumers a perception of high solids concentration

On average, the density increased by 17% from the first 25°Brix syrup concentration to reach 60°Brix nominal but in all treatments, a similar behavior was observed, where a slight increase of pH value was observed at gradually increase the concentration of the solutions, which was more pronounced in the Witness (Suc100) because the pH of a solution of 25°Brix sucrose is = 7.56; then descend, when acidification is done, before staining. Upon completion the impregnation, values near 3.63 pH were reached, in which erythrosine is precipitated and it allows the color fixation to the fruit.

As for the texture, significant differences for ANOVA (α = 0.05) and multiple range test was found, according to the Fisher test that showed that there was a difference between the groups formed by the Witness and T1 by and T2 and T3. This could be explained by the fact that the more heterogeneous the system of molecules is, the more it influences the shear strength of the final product. Witness and T2 treatments showed higher shear strength value than T3.

This can also be related to the differential hygroscopicity of sugars and mixtures that also affect the food hygroscopicity. In the case of polyols, which are

Table 1. Models adjusting °Brix variation with time for each treatment.

Stage	Treatment		Equation	R^2
1st Candying	Syrup	suc100	$y = 17.741x^{-0.0977}$	0.9215
		suc50-malt50	$y = 17.723x^{-0.1011}$	0.9524
		suc20-matl50-erit30	$y = 17.819x^{-0.095}$	0.9288
		malt55-erit30-mannit15	$y = 17.602x^{-0.1117}$	0.8959
	Cherries	suc100	y = 2.0906Ln(x) + 10.368	0.9936
		suc50-malt50	y = 2.3994Ln(x) + 9.2499	0.9253
		suc20-matl50-erit30	y = 2.4256Ln(x) + 9.6707	0.9652
		malt55-erit30-mannit15	y = 2.5574Ln(x) + 9.3375	0.9233
2nd Candying	Syrup	suc100	$y = 26.413x^{-0.0524}$	0.9092
		suc50-malt50	$y = 25.036x^{-0.0467}$	0.9821
		suc20-matl50-erit30	$y = 27.436x^{-0.0451}$	0.8565
		malt55-erit30-mannit15	$y = 26.061x^{-0.0343}$	0.8724
	Cherries	suc100	y = 1.6147Ln(x) + 20.051	0.8828
		suc50-malt50	y = 1.296Ln(x) + 18.61	0.9499
		suc20-matl50-erit30	y = 1.7529Ln(x) + 20.744	0.9896
		malt55-erit30-mannit15	y = 1.6409Ln(x) + 20.066	0.9601
3rd Candying	Syrup	suc100	$y = 36.79x^{-0.0265}$	0.9670
		suc50-malt50	$y = 35.686x^{-0.0219}$	0.9398
		suc20-matl50-erit30	$y = 37.224x^{-0.0308}$	0.9364
		malt55-erit30-mannit15	$y = 36.23x^{-0.0312}$	0.9023
	Cherries	suc100	y = 1.5685Ln(x) + 29.252	0.8740
		suc50-malt50	y = 1.6146Ln(x) + 26.446	0.9310
		suc20-matl50-erit30	y = 1.8706Ln(x) + 31.391	0.9918
		malt55-erit30-mannit15	y = 1.7559Ln(x) + 30.116	0.9625
4th Candying	Syrup	suc100	$y = 48.522x^{-0.0199}$	0.9204
		suc50-malt50	$y = 49.042x^{-0.0134}$	0.9281
		suc20-matl50-erit30	$y = 47.54x^{-0.0189}$	0.9776
		malt55-erit30-mannit15	$y = 47.034x^{-0.0196}$	0.8880
	Cherries	suc100	y = 1.6614Ln(x) + 37.532	0.8697
		suc50-malt50	y = 2.3134Ln(x) + 37.967	0.7974
		suc20-matl50-erit30	y = 1.9059Ln(x) + 41.40	0.9425
		malt55-erit30-mannit15	y = 2.1213Ln(x) + 40.426	0.8522
5th Candying	Syrup	suc100	$y = 59.061x^{-0.0117}$	0.9432
		suc50-malt50	$y = 59.934x^{-0.0077}$	0.8456
		suc20-matl50-erit30	$y = 60.085x^{-0.0119}$	0.8516
		malt55-erit30-mannit15	$y = 58.343x^{-0.0089}$	0.8923
	Cherries	suc100	y = 1.7172Ln(x) + 46.939	0.7569
		suc50-malt50	y = 1.2826Ln(x) + 48.622	0.8100
		suc20-matl50-erit30	y = 2.0751Ln(x) + 52412	0.9112
		malt55-erit30-mannit15	y = 1.9893Ln(x) + 50.458	0.8037

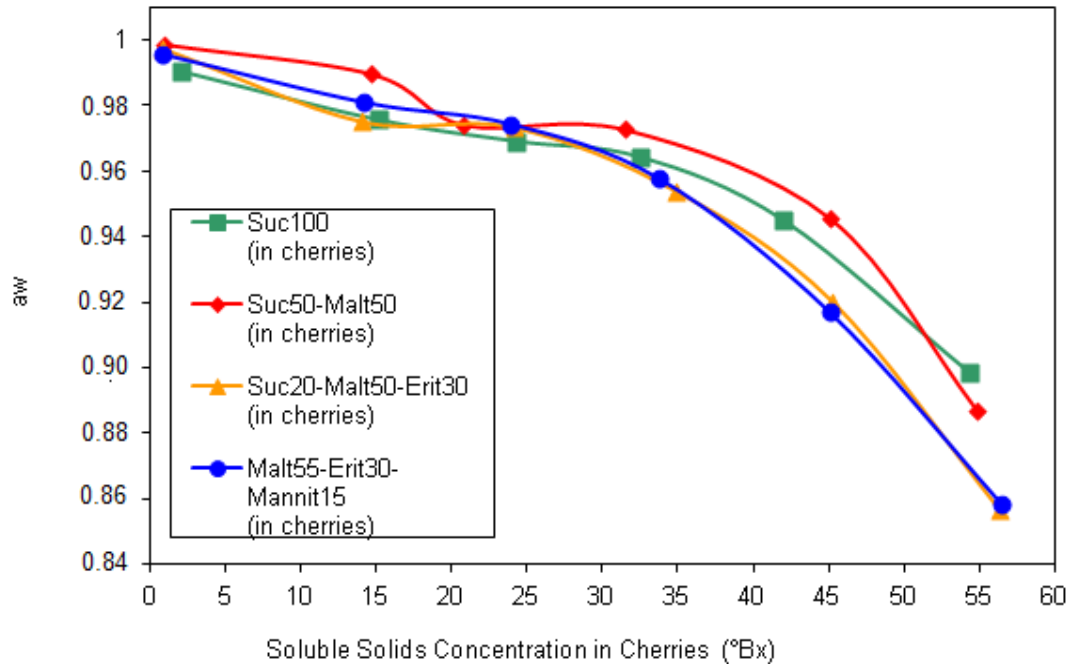

Figure 5. a_w cherries change versus concentration of Soluble Solids (°Brix) for the different treatments.

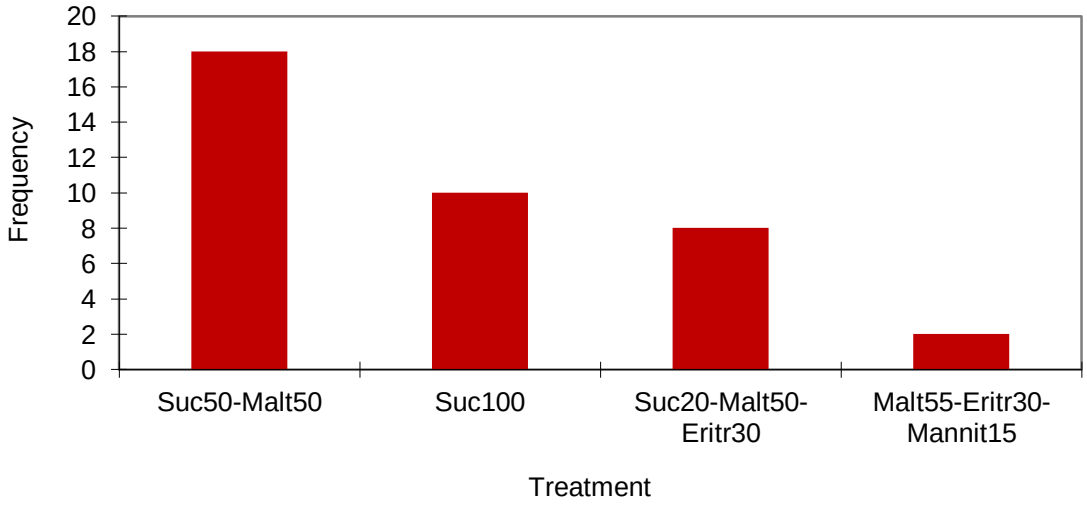

Figure 6. Preference test of cherries in syrup according to different treatments.

more hygroscopic than sucrose, these produce a moisturizing effect and thus tend to decrease the texture.

According to the results of sensory analysis (Figure 6) for satisfaction, the hedonic panel found differences in preference with regard to this attribute: the T1 was the highest qualified, scored (31), followed by the Witness (14). The T2 (2), and treatment with total replacement of sugar, T3 had negative score (-18). Color values thrown by colorimeter Minolta were also consistent with the sensory results and they showed significant differences between groups.

According to the results of satisfaction in hedonic scale Test, T1 (suc50-malt50) scored a higher rating from the panelists because the judges felt more balanced flavor generally, which also coincided with the higher red and yellow luminosity trend (L*, a* and b*; see Table 3); it was followed by the Witness (suc100), by its proper sweet taste, however some judges also found that it had sweetness excess. The T2 (suc20-eryt30-malt50) was placed third with a score (2); it was preferred, thirdly, very close to the Witness, elected by good taste and not too sweet. And finally the T3 (malt55-eryt30-man15) scored negatively (-18). As shown in Tables 2 and 6, T1 (suc-malt: 50-50%), with 50% reduction in sugars, a caloric

Table 2. Ingredients and calories intake/g.

Ingredients	kcal/g	Witness	T1	T2	T3
Sucrose	4	100	50	20	
Maltitol	2.1		50	50	55
Erythritol	0.2			30	30
Mannitol	1.6				15

Table 3. Colour.

Average/ treatment	Suc100	Suc50-Malt50	Suc20-Malt50-Erit30	Malt55-Erit30-Manit15
L*	28.16	31.24	28.68	28.58
a*	15.66	21.36	12.81	16.10
b*	4.11	7.48	5.34	6.47

value reduction of 19.9 % was achieved. In the T2 (suc-malt-eryt: 20-50-30%), with 80% reduction in sugars, a caloric value reduction of 48.2 % was achieved. In the T3 (malt-eryt-man: 55-30-15%) with 100% reduction in sugars, a caloric value reduction of 56.2% was achieved.

As shown in Table 3, the greater brightness value was reached with the T1 treatment (suc50-malt50), followed by the T3 treatment (malt55-erit30-manit15), the T2 treatment (sac20-malt50-erit30), and then the Witness treatment (suc100). The analysis of variance showed significant differences at a significance level of 5% for the four treatments. This showed that only the T1 treatment (sac50-malt50) is significantly different from the rest.

Again, the highest value of a* (+ a* is the red trend) was reached with Treatment 1 (suc50-malt50), meaning that which is closest to red. Then they followed the Treatment 3 (malt55-erit30-manit15), witness Treatment (suc100), and finally the Treatment 2 (suc20-malt50-erit30). The analysis of variance showed significant difference at a significance level of 5% for the different treatments. Treatment 1 (suc50-malt50) is again significantly different from the rest, and the witness is significantly different to the rest except with T3 (malt55-erit 30-mannit15).

Again, the largest value of b* (b* the yellow trend) was achieved with T1 treatment (sac50-malt50), meaning it is the closest to the yellow values. Then they followed the T3 treatment (malt55-erit30-manit15), T2 treatment (sac20-malt50-erit30), witness treatment (sac100). The analysis of variance showed significant differences at a level of significance of 5% compared to the witness treatment and T3 treatment (malt55-erit30-manit15) and T1 treatment (sac50-malt50), the latter being significantly different from T2 treatment (sac20-malt50-erit30).

As a general conclusion, we can say that 50% replacement of sucrose by maltitol in T1 treatment (suc50-malt50) caused a significant increase in lightness values L*, a* values (close to red tones) and b* (yellow) relative to the control (suc100).

According to Derache (1990), these polyols may have laxative effect in high doses, and have established a dose limiting their use, because they escape to intestinal absorption, they are fermented by colonic flora with gas production, and organic acids, which determines slight acidification and increases the moisture content and volume colon, favoring increased microbial activity and intestinal peristalsis, even though at low doses, such treatment did not cause problems in cherries consumption. Moreover, Grabitske and Slavin (2008) observed that LDC are well tolerated when consumed in solid foods, due to the increased transit time through the gastrointestinal tract, such as it occurs with cherries. Consumers can find relatively high doses acceptable if the amount is gradually increase and dividing the total daily intake in small portions throughout the day. For a safe level regarding the maximum daily dosage and allowed quantity for consumption without laxative effects, as seen in Table 4, a person can consume up to 28 cherries per day of T3 treatment, and up to 31 cherries per day for T1 and T2 treatments. There are no limits to the Witness treatment which lacks polyols. Anyway, these quantities are very rare in the intake of this product. Finally, regarding consumer tolerance, Livesey (2003) states that a consensus of food technologists and nutritionists has been established for the consumption of polyols: "Each individual can experiment with intake levels and make adjustments based on their own experience". This was recommended because for each individual the response to polyols ingestion may vary, and indeed they may do so to the extent that they may experience constipation.

As for nutritional value the following conversion factors were used (Table 2). From the results obtained, we can frame each of the treatments in different categories from the point of view of existing legislation (see Table 5). All treatments meet the "reduced caloric value" attribute, according to Article 235 of the CAA, subsection fifth, except T1 treatment (suc-malt: 50-50%). The T3 treatment (malt-eryt-man: 55-30-15%) meets the categories: "low calorific value" and "no added sugars".

Table 4. Laxative dosage and quantities for consumption.

Carbohydrates		Laxative dosage g / (day*person)	Witness	T1	T2	T3
Polyols amount consumed (g)	Maltitol	52	0	28.3	28.3	31.1
	Eritritol	-	0	0	17	17
	Manitol	15	0	0	0	8.5
Sucrose		Unrestricted	100	50	11	0
		Total	100	28.3	45.3	56.6
Amount of cherries laxative dosage (g)		Maltitol	0	184	184	167
		Erythritol	0	0	0	0
		Mannitol	0	0	0	177
Maximum number of cherries to consume average weight 6g			Unrestricted	31	31	28

Table 5. Argentinean food code classification.

Variable	Attribute	Witness	T1	T2	T3
Calorie Value	Reduced caloric value	Does not comply	Does not comply	Complies	Complies
Sugars	Low in sugar	Does not comply	Complies	Complies	Complies
	No added sugars	Does not comply	Does not comply	Does not comply	Complies

Table 6. Energy intake of carbohydrates, proteins and fats.

Tested analysis	Average		Witness	T1	T2	T3
Carbohydrates	56.62	g/100 g	226.5	161.4	108.1	82.4
Proteins	0.2	g/100 g	0.8	0.8	0.8	0.8
Total fats	0.06	g/100 g	0.5	0.5	0.5	0.5
Total calorie value	228	kcal/100 g	227.8	162.7	109.5	83.7
Sugars	56.42	g/100 g	56.4	25.4	11.3	0
Absolute difference caloric value		kcal/100 g		65.1	118.3	144.1
Caloric value reduction				0.286	0.519	0.633
Absolute difference value sugars		g/100 g		31	45.1	56.4
Sugars reduction				0.55	0.8	1

Treatments 1, 2 and 3 comply with category "low sugar". In Table 5, these categories are shown as well as, in Table 4, the consumption amount thereof according to the treatment, and the maximum of cherries that could be consumed per day”

CONCLUSIONS

The study shows that it is feasible to produce cherries in syrup with up to 56.2% reduction in caloric value. T1 product (suc-malt: 50-50%) with "low sugar" was achieved. The T2 treatment (suc-malt-eryt: 20-50-30%) with "reduced caloric value" with a 48.2% reduction in relation to Witness, and "low sugar" by 80%. The T3 (malt-eryt-man: 55-30-15%) with "reduced caloric value" with a 56.2% reduction, and meets the attribute "no added sugars" (100% without sugar).

The evolution of physicochemical variables such as: pH, density, soluble solids (°Brix) in and out of cherry, water activity (a_w) and color, were characterized, for the confit process and the finished product. The sucrose substitution with polyols had a significant effect ($\alpha = 0.05$) in the a_w reduction, the shear strength and color of the finished product. Sensorily, there were significant differences ($\alpha = 0.05$) by replacing sucrose, and T1 (suc50-malt50) was the treatment with best acceptance. A trend toward preference for a sweet taste but not as cloying was observed, which would be positive for the purpose of replacing sucrose for the less sweet compounds as polyols. This demonstrated the feasibility of developing "reduced caloric value" and "low sugar" products, for persons with special regimens, beneficial to their health.

ACKNOWLEDGEMENTS

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APPENDIX

The statistical analysis is shown in Supplementary Data and was done with the statistical program in its version in Spanish. Then, the graphs shown in this section have not been changed, so it shows comma instead of decimal point. However, all tables of statistical analysis, errors, mean value chart and box and whisker graphic for each parameter, are shown.

Water activity a_w

ANOVA

Table 1.

Source	Sum of squares	Gl	Mean square	F-ratio	P-value
Between-group	0.0044159	3	0.00147197	21.43	0.0000
Within-group	0.000824333	12	0.0000686944		
Total (Corr.)	0.00524023	15			

The ANOVA table (Table 1) decomposes the variance of the data into two components: a between-group and within-group component. The reason-F, which in this case is equal to 21.4278, is the ratio of the between-group estimate and the estimate within-groups. Since the P-value of F-test is less than 0.05, a statistically significant difference between the means of the 4 variables with a 95.0% level of confidence is given. To determine which means are significantly different from other, is selected Multiple Range Test.

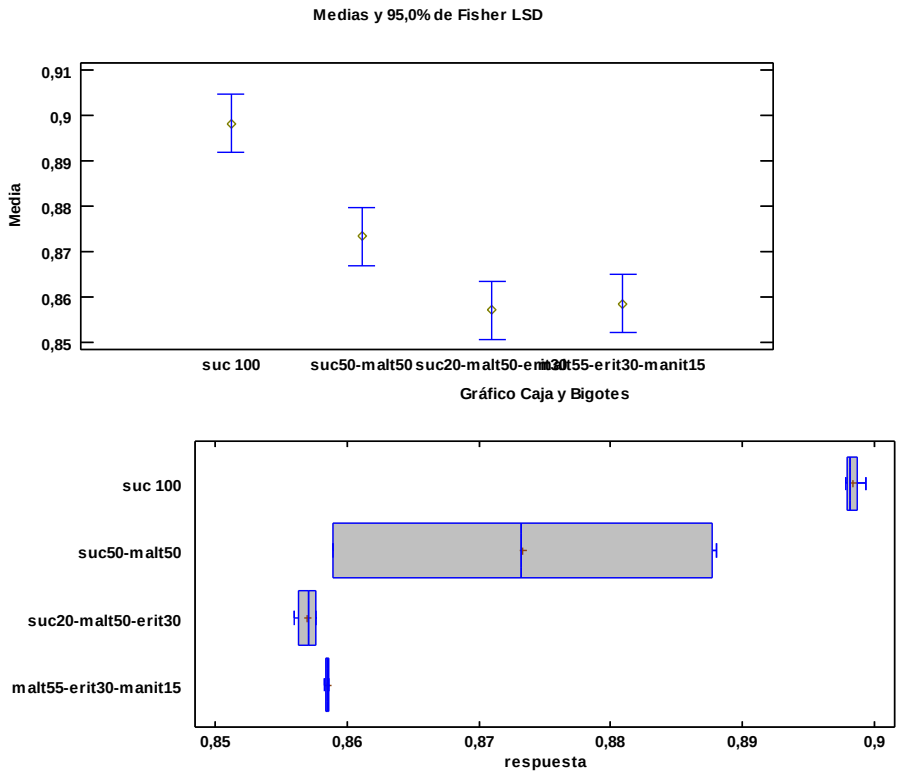
Multiple range tests

Method: 95.0 percentage LSD

Table 2:

	Cases	*Mean*	*Homogeneous Groups*		
suc20-malt50-erit30	4	0.85695	X		
malt55-erit30-mannit15	4	0.858475	X		
suc50-malt50	4	0.873325		X	
suc 100	4	0.898325			X

Table 2 applies a multiple comparison procedure to determine which means are significantly different from others. The bottom half of the output, shows the estimated between each pair of mean differences. The asterisk is next to the 5 pairs indicates that these pairs show statistically significant differences with a 95.0% level of confidence. At the top of the page, we have identified three groups according to homogeneous alignment of the X in columns. No statistically significant differences between those levels share the same column of X. The current method for discriminating between the means is the method of least significant difference (LSD) Fisher. With this method there is a risk of 5.0% to say each pair of tights is significantly different, when the actual difference is 0.



Texture

ANOVA

Table 3.

Source	Sum of squares	Gl	Mean Square	F-ratio	P-value
Between-group	121.939	3	40.6463	64.61	0.0000
Within-group	7.54959	12	0.629132		
Total (Corr.)	129.488	15			

The ANOVA table (Table 3) decomposes the variance of the data into two components: a between-group and within-group component. The reason-F, which in this case is equal to 64.6069, is the ratio of the between-group estimate and the estimate within-groups. Since the P-value of F-test is less than 0.05, a statistically significant difference between the means of the 4 variables with a 95.0% level of confidence is given. To determine which means are significantly different from other is selected Multiple Range Test.

Multiple range tests

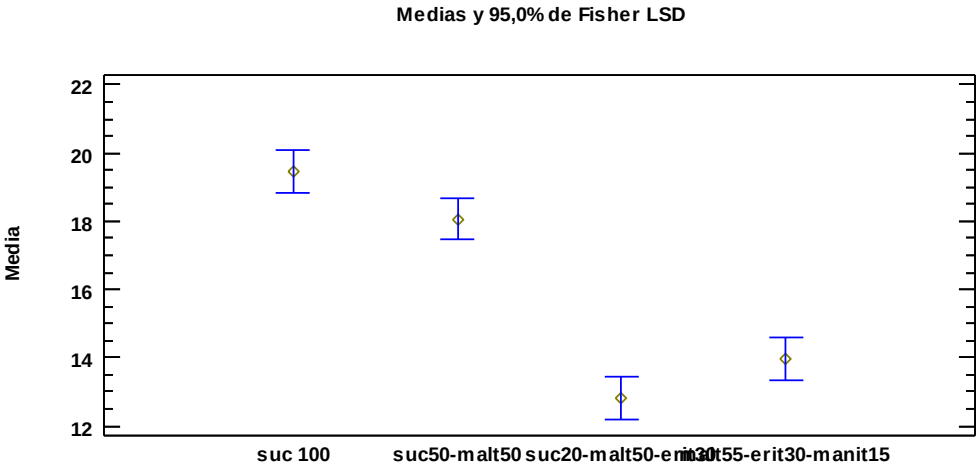
Method: 95.0 percentage LSD

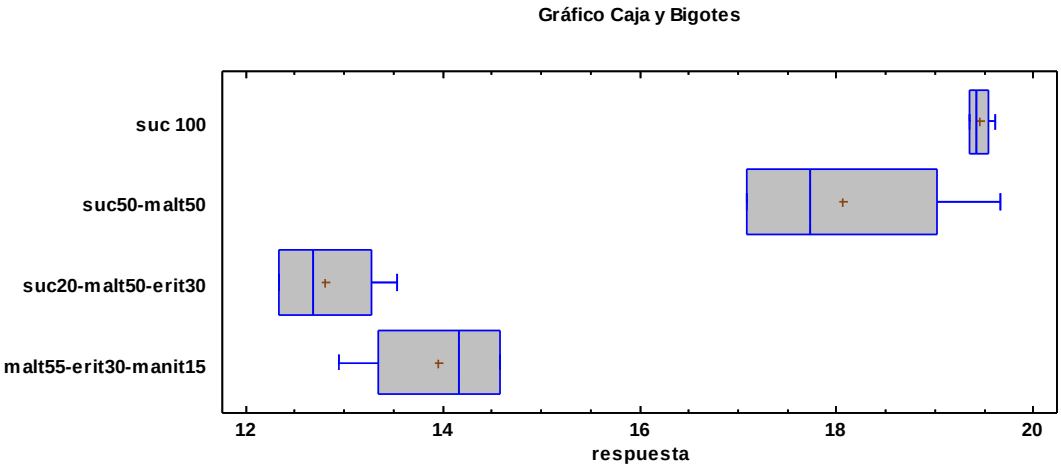
Table 4:

	Cases	Mean	Homogeneous Groups		
suc20-malt50-erit30	4	12.806	X		
malt55-erit30-mannit15	4	13.961	X		
suc50-malt50	4	18.058		X	
suc 100	4	19.451			X

* indicates a significant difference.

Idem a_w





Luminosity

L*

Method: 95.0 percentage LSD

Table 5:

	Cases	Mean	Homogeneous Groups	
suc 100	4	28.16	X	
malt55-erit30-mannit15	4	28.58	X	
suc20-malt50-erit30	4	28.6775	X	
suc50-malt50	4	31.2475		X

* indicates a significant difference.

The greater brightness value was reached with Treatment 1 (suc50-malt50), then followed him Treatment 3 (malt55-erit30-manit15), Treatment 2 (sac20-malt50-erit30), witness Treatment (suc100). The analysis of variance showed significant at a significance level of 5% for the four different treatments. This shows that only Treatment 1 (sac50-malt50) is significantly different from the rest.

a*

ANOVA

Table 6.

Source	Sum of squares	Gl	Mean square	F-ratio	P-value
Between-group	152.564	3	50.8546	18.98	0.0001
Within-group	32.1466	12	2.67889		
Total (Corr.)	184.71	15			

The ANOVA table (Table 6) decomposes the variance of the data into two components: a between-group and within-group component. The reason-F, which in this case is equal to 64.6069, is the ratio of the between-group estimate and the estimate within-groups. Since the P-value of F-test is less than 0.05, a statistically significant difference between the means of the 4 variables with a 95.0% level of confidence is given. To determine which means are significantly different from other is selected Multiple Range Test.

Multiple range tests

Method: 95.0 percentage LSD

Table 7:

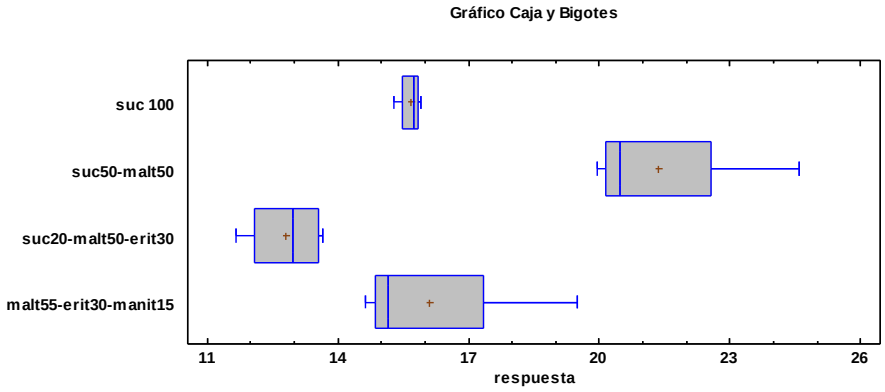
	Cases	Mean	Homogeneous Groups		
suc20-malt50-erit30	4	12.8075	X		
suc 100	4	15.66		X	
malt55-erit30-mannit15	4	16.1025		X	
suc50-malt50	4	21.3625			X

* indicates a significant difference.

Table 7 applies a multiple comparison procedure to determine which means are significantly different from others. The bottom half of the output, shows the estimated between each pair of mean differences. The asterisk is next to the 5 pairs indicates that these pairs show statistically significant differences with a 95.0% level of confidence. At the top of the page, we have identified three groups according to homogeneous alignment of the X in columns. No statistically significant differences between those levels share the same column of X. The current method for discriminating between the means is the method of least significant difference (LSD) Fisher. With this method there is a risk of 5.0% to say each pair of tights is significantly different, when the actual difference is 0.

Again, the highest value of a* (+ a* is the red trend) was reached with Treatment 1 (suc50-malt50), meaning that which is closest to red. Then they followed the Treatment 3 (malt55-erit30-manit15), witness Treatment (suc100), and finally the Treatment 2 (suc20-malt50-erit30).

The analysis of variance showed significant difference at a significance level of 5% for the different treatments. Treatment 1 (suc50-malt50) is again significantly different from the rest, and the witness is significantly different to the rest except with T3 (malt55-erit 30-mannit15).



b*

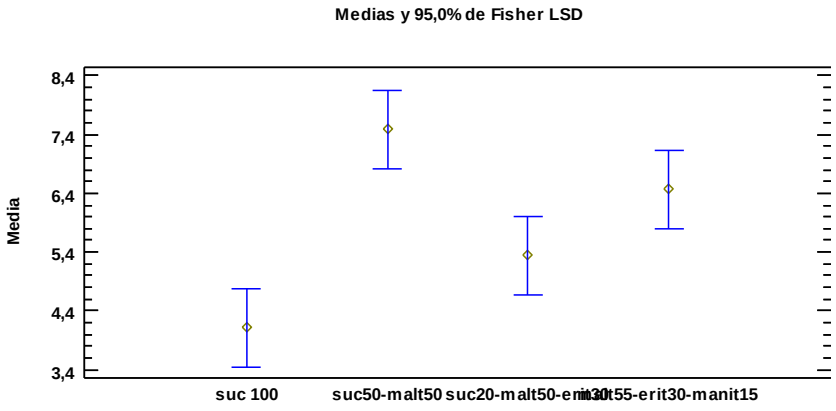
Multiple range tests

Method: 95.0 percentage LSD

Table 8:

	Cases	Mean	Homogeneous Groups			
suc 100	4	4.11	X			
suc20-malt50-erit30	4	5.34	X	X		
malt55-erit30-mannit15	4	6.4675			X	
suc50-malt50	4	7.845				X

* indicates a significant difference.



Again, the largest value of b* (b* the yellow trend) was achieved with T1 treatment (sac50-malt50), meaning it is the closest to the yellow values. Then they followed the T3 treatment (malt55-erit30-manit15), T2 treatment (sac20-malt50-erit30), witness treatment (sac100).

The analysis of variance showed significant differences at a level of significance of 5% compared to the witness treatment and T3 treatment (malt55-erit30-manit15) and T1 treatment (sac50-malt50), the latter being significantly different from T2 treatment (sac20-malt50-erit30).

No significant differences between T2 treatment (sac20-malt50-erit30) and T3 treatment (malt55-erit30-manit15).

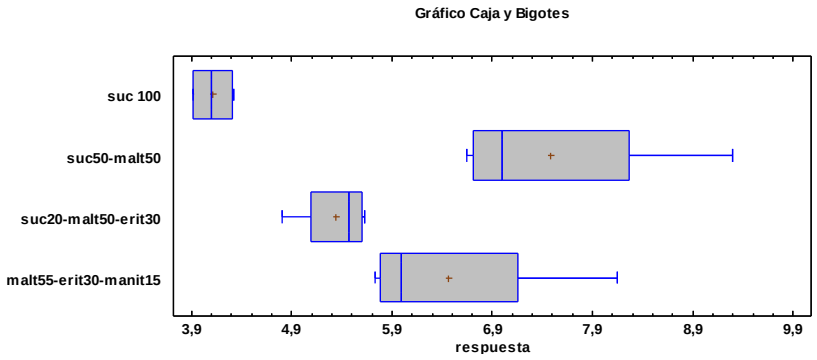


Gráfico Caja y Bigotes
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suc20-malt50-erit30
malt55-erit30-manit15
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