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Sustainable performance of cold-set gelation in the confectionery manufacturing and its effects on perception of sensory quality of jelly candies

Matheus Henrique Mariz de Avelar [a], Guilherme de Castilho Queiroz [b], Priscilla Efraim [a,*]

[a] University of Campinas (UNICAMP), School of Food Engineering (FEA), 13083-862, Campinas, SP, Brazil
[b] Cereals and Chocolate Research Center (CEREAL CHOCOTEC), Food Technology Institute (Ital/APTA/SAA – Secretariat of Agriculture and Supply), State Government of São Paulo, Brasil, Avenida Brasil, 2880, Jardim Chapadão, Campinas, São Paulo, 13-070-178, Brazil

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A B S T R A C T

Finding new technologies for enhance the sustainable confectionery production is desirable. In this context the cold-set gelation emerges as potential tool for the jelly candy industry. This study evaluated sustainability aspects of alginate/pectin cold-set gelation technique in the jelly candy manufacturing process and its impacts in sensory quality of the obtained products. The energy requirement and the CO_2 emissions of cold-set jelly candy processing were measured, comparing to the conventional jelly candy manufacturing process. The produced candies were evaluated in relation to the bioactive compounds content (ascorbic acid, total phenolic and total anthocyanin compounds) and sensorially evaluated in acceptance tests wherein healthy and environmental sustainability labeling were put to the test. A questionnaire of purchase behavior was also applied to voluntary consumers. The results indicated the cold-set processing had lower energy demand (99 times lower) and gas emission (300 times lower) compared to the conventional manufacturing. Cold-set jellies showed about 3.3 times more phenolic compounds and 1.22 times more acid ascorbic content than pectin jellies. The consumer informed high interest and willing to pay more in jelly candy with sustainability labeling, however they showed low knowledge and frequency of consumption of these products. Results from the sensory acceptance test showed no significant difference ($p < 0.05$) between the candies regarding the attributes, but when sustainable claims were labeled it was verified an increasing in the sensory acceptance for appearance, texture and overall impression of the cold-set candies, suggesting the sustainable marketing potential of cold-set jelly candy manufacturing processing.

1. Introduction

Jellies and gummies are a popular and significant growing class of confections in the candy market [1]. They comprise a broad group of products elaborated from mixture of sugar syrups and hydrocolloids (gelling agent), such as gelatin, starch and pectin [2]. Their technological and organoleptic characteristics vary according to the hydrocolloid used and the final moisture content of the confection [3].

In recent years the candy market has been stimulated by confectionery launches with claims of healthiness, functionality, fortified formulation and sustainability on their labels [4]. The growing interest of consumers for adequate the diet has been increased the demand for find more conscious, convenient, nutritious and natural food options [5].

The candy industry has been found in the segment of gummies and jellies with fruit ingredients a great market strategy for attend claims of healthiness and naturalness. Fruit jelly candies stand out for their sensory quality, reformulation with less sugar content and no adding synthetic dyes and flavors [6].

For sustainability claims there has been a great focus of candy industry on sustainable manufacturing processes such as organic, “fair trade” and other production methods that aim reducing energy consumption and waste emissions for the environment along all food processing chain and packaging [7].

Claimed launches requires the regulation of labels to current legislation and technical standards. Formulations with natural ingredients and improved nutritional composing must follow the food labeling guidelines [8]. For environmental claims, the incorporation of environmental auditing or third party certification obtaining are necessary for

* Corresponding author.
E-mail address: pris@unicamp.br (P. Efraim).

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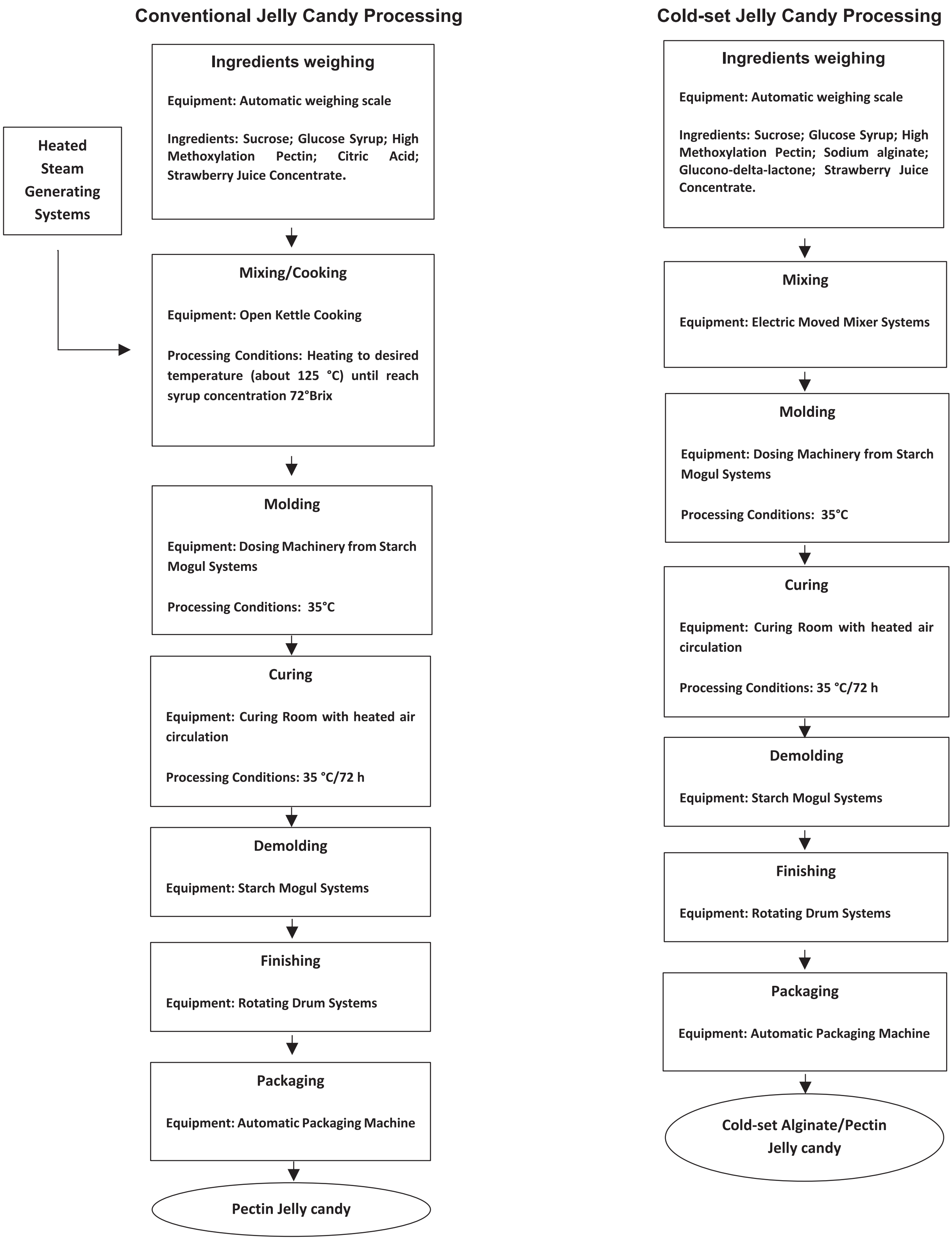

Fig. 1. Flowchart of conventional pectin jelly candy processing and cold-set jelly candy manufacturing.

implement environmental labeling on their products [9]. In this context the International Standards Organization (ISO) certification packaging is constantly requested [10].

The self-declared environmental claims are the most numerous sustainable labels worldwide. They are a cheap and easily applicable option to show environmental information for the consumer and they are based on self-declarations by manufacturer or retailers [10]. Eco-labels, energy labels, green stickers, carbon labels and product labels are examples of the diversity of environmental labels [11].

There is a growing segment of consumers disposed to pay more for green products as energy-efficient products and carbon reduction potentials [12]. In this context new technologies and strategies aiming to enhance the environmental management of confectionery processing industry have been extendedly evaluated and reported by the scientific literature. Among the recently appointed alternatives, the cold-set gelation technology applied to jelly candy manufacturing is noteworthy [13].

Cold-set gelation is the technique of obtaining gels by combining certain hydrocolloids under specific conditions with no heating. This technique present applicability in industrial processing of products with low thermal stability [14]. Sodium alginate and high methoxylation pectin are two gelling agents with specific capacity of cold-set gelation. When mixed in a medium at pH 3.4–3.8, these hydrocolloids can structure cohesive nets at room temperature [15].

Recent studies have been suggested the sodium alginate/high methoxylation pectin cold-set gelation as a potential sustainable technology able to replace the conventional jelly candy manufacturing process due its promising lower energy requirement [13] and its low processing temperatures which enable the maintenance of thermosensitive compounds of fruit ingredients and obtaining fruit candies with higher nutritional value [16].

The conventional manufacturing of jellies and gummies differ slightly according to the gelling agent, but in general all they follow the same steps of (i) ingredient mixing (for dissolving all sweeteners and solubilize hydrocolloid); (ii) cooking (for reduce water content and induce gelation); (iii) cooling the syrup and adding food additives (colors, flavors and acids); (iv) syrup dosing in dried starch powder molds (in starch mogul systems); (v) Curing or stoving (drying of molded candies in curing rooms for remove the excess moisture, cool and solidify the candies); (vi) finishing (covering the candies with oil or sugar coating) [3].

Several machinery systems can be used for the cooking step such as batch kettle cooking, vacuum cooking, swept surface heat exchanger, and coil cooking [3]. According to Aigroup [17], cooking systems and the hot water and boiler systems, which provides energy for the cooking equipment, are among the most energy intensive activities in confectionery manufacturing lines beside cool rooms, cooling towers and conveying systems.

Hot water and boiler systems in too many countries are operated with fossil energy resources (coal, oil, natural gas and secondary fuels), which presents environmental disadvantages such as high carbon footprint [18]. The fossil fuels burning levels vary according the country consume, but it is estimated they provide about 37% of the total global CO_2 emissions [19].

The industrial production of jellies and gummies correspond to about 25% of the energy consumption of all the confectionery sector, consuming more than 294 GWh of primary energy and emitting 60,000 t CO_2 emissions a year [20].

Aiming the reduction of energy requirement and environmental emissions from jelly candy production the cold-set gelation stands out as an alternative for the cooking step. According Avelar & Efraim [13] alginate/pectin cold-set gelation enables obtaining sweet gelled structures, with no heating requirement following the steps of (i) ingredient mixing; (ii) direct syrup dosing in dried starch molds; (iii) curing or stoving; and (iv) finishing. In cold-setting manufacturing the machineries of the conventional cooking step are replaced for electric-moved mixing equipment and heat generation systems are not required, reducing energy demand and environmental emissions of the candy manufacturing line.

The researches published to date have been evaluated the cold-set processing only on laboratory scale [16]. Its sustainability potential, however, still needs be analyzed on higher scales for better estimate the environment impacts to industrial lines.

The possibility of obtaining environmental claims by this new technology and attributing to the developed products also must be evaluated, as well as its effect on the sensorial consumer acceptance. Considering the studies about sensory perception of environmental labeled candies and consume behavior are too scarce in the literature, these data can be an important source to guide the industrial confectionery sector.

Table 1
Strawberry jelly candies formulations.

Ingredients	Quantity (g/kg)	
	Strawberry cold-set jelly candy	Strawberry pectin jelly candy
Sucrose	440	465
Glucose syrup	110	120
Strawberry juice concentrate	400	395
Sodium alginate	20	–
High methoxylation pectin	20	14
Glucono-delta-lactone	10	–
Citric acid	–	6

Source: Avelar et al. [16].

In this context, the aim of this study was to evaluate the sustainable performance of sodium alginate/high methoxylation cold-set gelation technique as a tool for jelly candy processing compared to the conventional manufacturing process in transposed processing scale lines, and verify the impact of sustainable claims on the label of the produced candies in its sensory acceptance.

2. Material and methods

2.1. Material

Ingredients used for jelly candy production: citric acid (ACS, Synth, Diadema, Brazil), high methoxylation pectin (HM 121Slow, Degree of esterification 58%, CPKelco, Limeira, Brazil), glucono-delta-lactone (GDL) (Art Alimentos, São Paulo, Brazil), glucose syrup (Excell 1040, Ingredion, Mogi Guaçu, Brazil), sodium alginate (Algin I-3G-150, viscosity 300–400 mPa s, Kimica, Providencia, Chile), strawberry juice concentrate (30 °Brix, Loop, Piracicaba, Brazil), sucrose (refined sugar, União, São Paulo, Brazil).

2.2. Definition of boundaries of the study

The flowcharts of conventional pectin jelly candy processing (HCP), described by Hartel [3], and alginate/pectin cold-set jelly candy processing (CSCP), developed by Avelar & Efraim [13], are presented in Fig. 1. Comparing the two processes it is identified they share the same steps of ingredient weighting, syrup dosing, curing, demolding, finishing and packaging (with same machinery and processing conditions).

Three mainly differences, however, can be appointed: (i) Ingredients of formulation (cold-set jellies requires both sodium alginate and pectin as gelling agents and glucone-delta-lactone as acidulant instead citric acid); (ii) Heat requirement for operating cooking machinery in pectin jellies processing; and (iii) quality of final products (as previously described different hydrocolloids provide candy gels with distinct properties).

Considering the contrasting points between the manufacturing processes, the boundaries of this present study were delimited as the following points:

(i) Ingredients: Analysis of economic impact of replacement the recipe of pectin jelly candy for alginate/pectin cold-set jelly candy;
(ii) Candy syrup preparing step: Analysis of the sustainable potential of cold-set candy syrup mixing step compared to conventional cooking step by the measurement of energy requirement and CO_2 emissions;

(iii) Final products: Analysis of the quality of cold-set jellies, the potential of healthiness and environmental sustainability claiming and its effects on sensory acceptance.

2.3. Economic analysis of jelly candy formulation

A strawberry cold-set jelly candy (CSC) and a strawberry pectin jelly candy (HC) formulated by Avelar et al. [16] (Table 1.) were suggested for conduction of this study, aiming to obtain natural confections with high content of bioactive compounds and due to the great acceptability and widely use of strawberry flavor in confectionery products.

The price quote of each ingredient in 2019 year was inquired directly to the producing or reselling companies [21] and the total cost of the candy recipe was calculated considering the ingredients percentage in the formulations. The final cost was adjusted to the processing yield factors (calculated in item 2.4.2), for be expressed in price (US$)/kg of produced candy.

2.4. Sustainability analysis of cold-set jelly candy processing

2.4.1. Jelly candy manufacturing processes definition

CSCP followed the steps: (i) dissolution of sucrose and glucose syrup in strawberry juice concentrate, (ii) dispersion of gelling agents (alginate and pectin) in the solution of sugars and fruit juice, (iii) dissolution of glucono-delta-lactone (GDL) to acidify the system, (iv) dosing of final candy syrup in starch molds and (v) drying in a forced air circulation drying oven (Tecnal, model TE-394/2, Piracicaba, Brazil) at 35 °C/72 h [16].

HCP was performed by dissolution of the ingredients and cooking at atmospheric pressure until 71 °Brix, dosing the final candy syrup into starch molds, and drying in the same forced air circulation drying oven at 35 °C for 72 h [22]. Two batches of each candy sample at different scales were produced for a comparing evaluation of energy requirement of the processes: a bench-scaled batch and a pilot plant scale batch.

The bench scaled CSCP was performed with a digital mechanical bench agitator (Tecnal, model TE-039/1, Piracicaba, Brazil) at 380 rpm. The length time of mixing steps was fixed at 3.44, 0.78, and 0.86 min for steps (i), (ii), and (iii), respectively. The bench scaled HCP was carried out in a gas burning bench cooker with cooking time fixed at about 5.12 min (until 71 °Brix was reached). The burned gas was a liquefied petroleum gas consisting of 750 g/kg isobutane and 250 g/kg propane. The CSC and HC syrups were manually dosed with a funnel and the candies were dried in a forced air circulation drying oven (Tecnal, model TE-394/2, Piracicaba, Brazil).

Both plant scale candy processes were performed at the Fruit, Vegetable and Confectionery plant pilot of the University of Campinas (School of Food Engineering, UNICAMP, São Paulo, Brazil) with a jacketed pot (Geiger, model UMM SK12, Pinhais, Brazil) at 1750 rpm. The jacket pot rotor was used for ingredients mixing in CSCP with no steam applying. The length of the mixing time steps was fixed at 1.00, 0.66, and 1.50 min for steps (i), (ii), and (iii), respectively.

The HCP was performed at 2.50 min with steam pressure 1.00 kgf/cm^3. The steam generating boiler (Domel, model VSVG.310, São Paulo, Brazil) was operated with 3 kgf/cm^3 steam pressure, gas consumption per hour: 22.73 kg/h, and LPG gas as burning fuel.

2.4.2. Measurement of the energy requirement and CO_2 emissions of candy syrup processing steps

The direct differences of requirements and emission between CSCP and HCP are related to the syrup preparing step, for that reason the comparing study was bounded to this step. The energy requirements of CSCP in both processing scale were measured considering the time of candy syrup preparation and the power of the equipment (bench agitator power: 180 W, jacket pot power: 2 kW) according to Equation (1) [23].

$$\text{Energy requirement (kWh)} = \frac{\text{time of the process (s) x power of the equipment (W)}}{3600\left(\frac{\text{s}}{\text{h}}\right) \text{x} \, 1000\left(\frac{\text{W}}{\text{kW}}\right)} \quad \text{(Equation 1)}$$

The energy requirement of both scaled HCP was calculated according to Equation (2) [24], considering the volume and the internal calorific value of the gas burned during the heating of the candy syrup (*bench scale*: isobutane internal calorific value: 9,209 kJ/m^3, propane internal calorific value: 117,230 kJ/m^3; *pilot scale*: liquefied petroleum gas: 11, 000 kcal/kg) [25].

$$\text{Energy requirement (MJ)} = \text{Gas volume } (\text{m}^3) \text{ x Internal calorific value } \left(\frac{\text{MJ}}{\text{m}^3}\right) \quad \text{(Equation 2)}$$

The weight yield of each jelly candy process was calculated considering the mass loss by evaporation during the cooking step and moisture loss during drying step (Equation (3)). The energy requirement of the processes was adjusted to the weight yield and expressed by MJ/kg of produced candy.

$$\text{Weight yield} = \frac{\text{weight of candies after drying step (kg)}}{\text{weight of candy syrup before cooking or cold} - \text{setting step (kg)}} \quad \text{(Equation 3)}$$

For CSCP the estimation of carbon dioxide emissions was performed considering the average annual CO_2 emission factor for Brazilian electricity [26], while for HCP it was calculated considering the Brazilian CO_2 emission factor for direct burning [27].

2.4.3. Measurement of indirect requirements of energy and resources

The indirect requirement of resources related to boiler consumption of energy, water and fuel for steam production in HCP was calculated. The electric energy demanding was estimated using Equation (1) (item 2.4.2) considering HCP time (2.50 min) and power of the boiler (232.6 kW). The fuel consumption was determined by the hourly consumption rate (22.73 kg LPG gas/h) and processing time.

The water requirement was calculated by the hourly steam production factor with water supply at 20 °C (311 kg steam/h) during the time of operation. The CO_2 emissions were estimated by the sum of direct emissions from fuel combustion and indirect emissions from electricity consumption according methods described in item 2.4.2.

2.5. Evaluation of the quality of jelly candies

2.5.1. Bioactive compounds content

The bioactive compounds content of the produced candies was evaluated in order to verify the possibility of attributing claims of healthiness on the label of the obtained products. The ascorbic acid content was analyzed by the titratable method according to Cheftel & Pigeaud [28]. The phenolic compounds content was measured using Folin Ciocalteu reagent, with a spectrophotometer (model Cirrus 80, Femto, São Paulo, Brazil) at 765 nm [29].

The total anthocyanin content was determined by pH differential spectroscopic method according to Tonutare et al. [30]. Two buffer solutions were used: 0.025 M potassium chloride (pH 1.0) and a 0.4 M sodium acetate (pH 4.5). Ethanol solvent 0.1 M HCl (85: 15%, v: v) was used to the extraction. The measurements were carried out on the same spectrophotometer as mentioned above at 510 and 700 nm. The absorbance of the diluted sample (A) was calculated by Equation (4) and the total anthocyanin content by the Equation (5).

$$A = (A_{510} - A_{700})_{pH\ 1.0} - (A_{510} - A_{700})_{pH\ 4.5} \quad \text{(Equation 4)}$$

$$Total\ anthocyanin\ content \left(\frac{mg}{100g}\right) = \frac{A\ x\ M\ x\ DF\ x\ 1000}{(\varepsilon\ x\ \lambda\ x\ m)} \quad \text{(Equation 5)}$$

Table 2
Cost analysis of jelly candy formulation.

Ingredients	Price (US$/kg)	Food Brand	Source
Sucrose	1.30	–	USDA/ ERS[a]
Glucose syrup	0.79	–	USDA/ ERS[a]
Strawberry juice concentrate	4.09	Loop	Direct quote[b]
Sodium alginate	44.09	Master Sense	Direct quote[b]
High methoxylation pectin	22.05	Cargill	Direct quote[b]
Glucono-delta-lactone	3.90	Art Alimentos	Direct quote[b]
Citric acid	0.65	Ensign	Direct quote[b]
Formulation	**Price (US$/kg of candy syrup)**	–	–
Cold-set jelly candy formulation	3.65	–	–
Pectin jelly candy formulation	2.62	–	–
Jelly candies	**Price (US$/kg of produced candy)**	–	–
Strawberry Cold-set jelly candy	2.34	–	–
Strawberry Pectin jelly candy	1.94	–	–

[a] Average of world refined sugar price and wholesale price for glucose syrup in 2019 according the Economic Research Service of United States Department of Agriculture [33].
[b] Direct quote made with the producing company or reseller companies.

In the Equation (5), “A” is previously calculated absorbance, “M” is the molecular weight of cyanidin-3-glucoside (449.2 g/mol), DF is the dilution factor, ϵ is the molar absorptivity coefficient (29,600 L mol^{-1} cm^{-1}), λ is the cuvette optical pathlength (1 cm) and m is the weight of the sample (g) [30].

2.5.2. Sensory analysis

A sensory analysis test was carried out at the Food Sensory Analysis Laboratory of the Department of Food Technology - FEA/UNICAMP (Certificate of Presentation for Ethical Assessment - CPEA 86627118.5.0000.5404). The candies were evaluated in an acceptance test by 120 evaluators in relation to the attributes appearance, color, aroma, flavor, texture and overall impression, using a structured 9-point hedonic scale ranked 9: I liked it extremely and 1: I disliked it extremely [31].

The sensory test was divided into three sessions for evaluating the impact of labels on sensory acceptance and purchase intention. In the first session the evaluators performed a blind test, in which samples of CSC and HC were served with no information. Before the second session they received a card with explanations about products with sustainability claims: self-declared environmental label, naturalness (identification of natural ingredients) and healthiness (identification of high nutrients content). Then, they answered a questionnaire on consumer awareness for the product, elaborated according to Silva et al. [32] with modifications.

In the second session the consumers evaluated once again CSC and HC, but this time the samples were identified with designation of environmental sustainability (energy requirement and CO_2 emission) according to results obtained in item 2.4.2.

In the third session the candy samples were labeled with the same environmental sustainability information from second session, but this time the labeling was added by healthiness claims (bioactive compound content) according to values measured in item 2.5.1.

2.6. Statistical analysis

The data were submitted to Analysis of Variance (ANOVA), Tukey’s test, Friedman’s test and Nemenyi’s test at 5% significance level using XLSTAT statistical software (Addinsoft, New York, NY, 2016). The questionnaire reliability was determined with Cronbach’s alpha coefficient [33].

3. Results and discussion

3.1. Economic analysis of jelly candy formulation

The price of raw materials and the cost of jelly candy formulations are presented in Table 2. Considering the manufacturing processes yields the

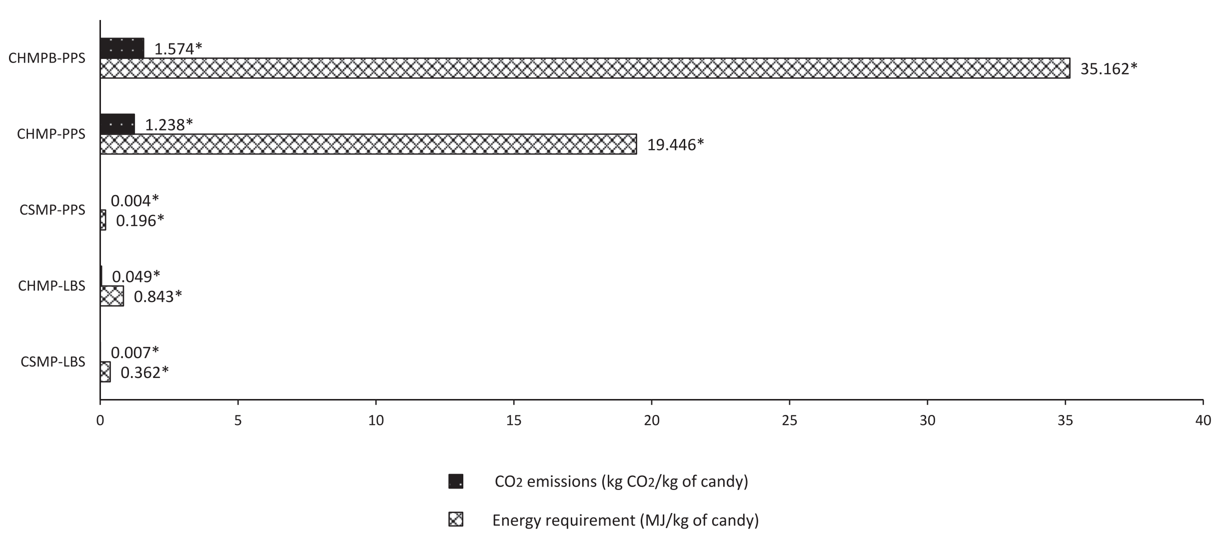

Fig. 2. Energy Requirement and Environmental Emissions of Candy Manufacturing Processes (CSMP: Cold-set Manufacturing Process; CHMP: Conventional Heating Manufacturing Process; CHMPB: Conventional Heating Manufacturing Process considering Steam Boiler Activity) in different Processing Scales (LBS: Lab Bench Scale; PPS: Pilot-Plant Scale) Mean values of CO2 emissions/energy requirement of different manufacturing processes at the same evaluated scale followed by (*) are significantly different ($p < 0.05$).

Table 3
Bioactive compounds contents of strawberry jelly candies.

Samples	Chemical parameters		
	AA (mg ascorbic acid g^{-1})	TPC (mg gallic acid g^{-1})	TAC (mg cyanidin-3-glycoside g^{-1})
Strawberry cold-set jelly candy	734.083 ± 13.10*	254.44 ± 35.64*	0.0515 ± 0.0201
Strawberry pectin jelly candy	597.376 ± 84.08*	76.66 ± 10.00*	0.0560 ± 0.0000

AA, ascorbic acid content; TPC, total phenolic compounds content; TAC, total anthocyanin content. Mean values followed by (*) in the same column are significantly different ($p < 0.05$).
Source: Avelar et al. [16].

CSC price per kg was 0.20 times higher than HC price.

Despite the cost, CSCP still must be considered due its promising environmental impacts. Once sustainability claims are allowed to label CSC, the final higher market price may be supported by environmental marketing strategic. In addition, it's important to highlight that gummy and jellies produced with other hydrocolloids may have recipe costs equal or even higher than CSC due to price and required quantity of gelling agent. Gums and drops produced with arabic gum, for example, can reach very higher charges due cost, volatility prices, and high hydrocolloid usage level (20–50%) in the recipes [3].

3.2. Direct and indirect energy requirement and CO_2 emissions

The processes presented energy requirement with significant difference ($p < 0.05$) on both evaluated scales (Fig. 2). HCP had an energy demand/volume of produced candy two times higher than CSCP on lab bench scale, and 97 times higher on pilot plant scale.

For HCP the boiler demanded 0.426 kg fuel, 5.837 L water and 15.716 MJ electric energy for kg of produced candy. Considering these rates, the total energy requirement of pilot plant scaled HCP was 179 times higher than CSCP.

Changing steam-powered cooking process for electric-powered mixing step makes boiler systems not necessary, implying in cost saving for industrial installation and operation. Furthermore, as only electric energy is required in cold-setting processing line, the environmental emissions are indirect and reduced, as well as resource consumption.

The volume of CO_2 emission of pilot plant scaled CSCP was 309 times lower than HCP and 393 times lower than HCP when considered the emissions from boiler operating. The appointed reduction of environmental emissions is very promising and desirable due the significant share of jellies in candy market.

Gums and jellies are the third-largest segment of sweet products, corresponding to about 20.64% of the global sugar confectionery market in terms of revenue [34]. Brazil follows United States and Germany in the ranking of world largest confectionery manufacturer, with 2019 production of more than 257,000 t of candies [35].

The global warming potential estimated by Nilsson et al. [36] for sugar confectionery products is about 3.92 kg CO_2-eq/kg of product. Considering the rates of reduction in CO_2 emissions between CSCP and HCP the cold-set gelation may contribute positively for environmental impact in the global confectionery industry chain.

The search for lower environmental impact in the confectionery industry by the energy saving and CO_2 emission reducing have also been reported by many other studies in the literature. Miah [37], for example, developed methodological tools based on heat integration and Life Cycle Assessment (LCA), evaluating a heat integration framework with combined direct and indirect heat exchange from zonal to multiple zones, and incorporating heat pump technology to enhance low grade heat recovery. It was concluded that heat integration can reduce factory energy consumption by 4.04–6.05% while the energy reduction by the heat pump technology is by up to 29.2%, despite the complexity design impose and long economic paybacks.

Table 4
Sensory attributes of the produced candies at blind and informed sessions.

Sensory attributes	Sensory test	**Average score**	
		Strawberry cold-set jelly candy	strawberry pectin jelly candy
Appearance	Blind sensory test	5.8 ± 1.7 b	5.7 ± 1.9 a
	Sensory test with suitability information	6.6 ± 1.5 a*	5.8 ± 1.7 a*
	Sensory test with healthiness and suitability information	6.7 ± 1.7 a*	5.9 ± 1.9 a*
Color	Blind sensory test	6.0 ± 1.7 a	6.8 ± 1.5 a
	Sensory test with suitability information	6.3 ± 1.7 a	6.7 ± 1.5 a
	Sensory test with healthiness and suitability information	6.4 ± 1.7 a	6.8 ± 1.5 a
Aroma	Blind sensory test	6.1 ± 1.4 a	6.1 ± 1.5 a
	Sensory test with suitability information	5.9 ± 1.3 a	5.8 ± 1.3 ab
	Sensory test with healthiness and suitability information	6.0 ± 1.3 a	5.7 ± 1.3 b
Flavor	Blind sensory test	6.4 ± 1.9 a	6.6 ± 1.7 a
	Sensory test with suitability information	6.5 ± 1.8 a	6.4 ± 1.9 a
	Sensory test with healthiness and suitability information	6.7 ± 1.7 a	6.3 ± 1.8 a
Texture	Blind sensory test	5.0 ± 2.2 b*	4.7 ± 2.3 a*
	Sensory test with suitability information	5.7 ± 2.0 a*	4.9 ± 2.2 a*
	Sensory test with healthiness and suitability information	6.1 ± 1.9 a*	4.8 ± 2.1 a*
Overall impression	Blind sensory test	5.9 ± 1.7 b	5.8 ± 1.8 a
	Sensory test with suitability information	6.4 ± 1.6 a*	5.8 ± 1.6 a*
	Sensory test with healthiness and suitability information	6.6 ± 1.6 a*	5.8 ± 1.5 a*

Mean values followed by (*) in the same line are significantly different ($p < 0.05$) in relation to the same sensorial attribute at the same sensory test session. Mean values of different sensory test sessions followed by the same letter in the same column are not significantly different ($p > 0.05$) in relation to the same sensorial attribute.

Jou et al. [38] studied the complete replacement of natural gas by the recovered waste tail gas emitted from petrochemical processes and verified a save 5.8×10^6 m^3 of natural gas consumption of furnace, which implies to reducing 3.5×10^4 t of CO_2 emission annually.

The energy demand and CO_2 emissions quantified in this study indicate the possibility of appointing environmental self-declared claims such as "reduced energy consumption and carbon footprint" in the CSC label.

3.3. Evaluation of the quality of jelly candies

3.3.1. Bioactive compounds content

CSC presented higher averages ($p < 0.05$) for total phenolic compounds and ascorbic acid content (Table 3) proving CSCP efficiency for maintenance of thermosensitive compounds of fruit ingredients during candy manufacturing [16].

Ascorbic acid (vitamin C) is an important water-soluble vitamin with physiological, anticarcinogenic and antioxidant functions [39] which stability is influenced by the presence of oxygen, high temperature and high or low water activity [40]. The Food and Agriculture Organization/World Health Organization (FAO/WHO) indicates 45 mg of vitamin C per day as recommended nutrient intake for adults [41]. The

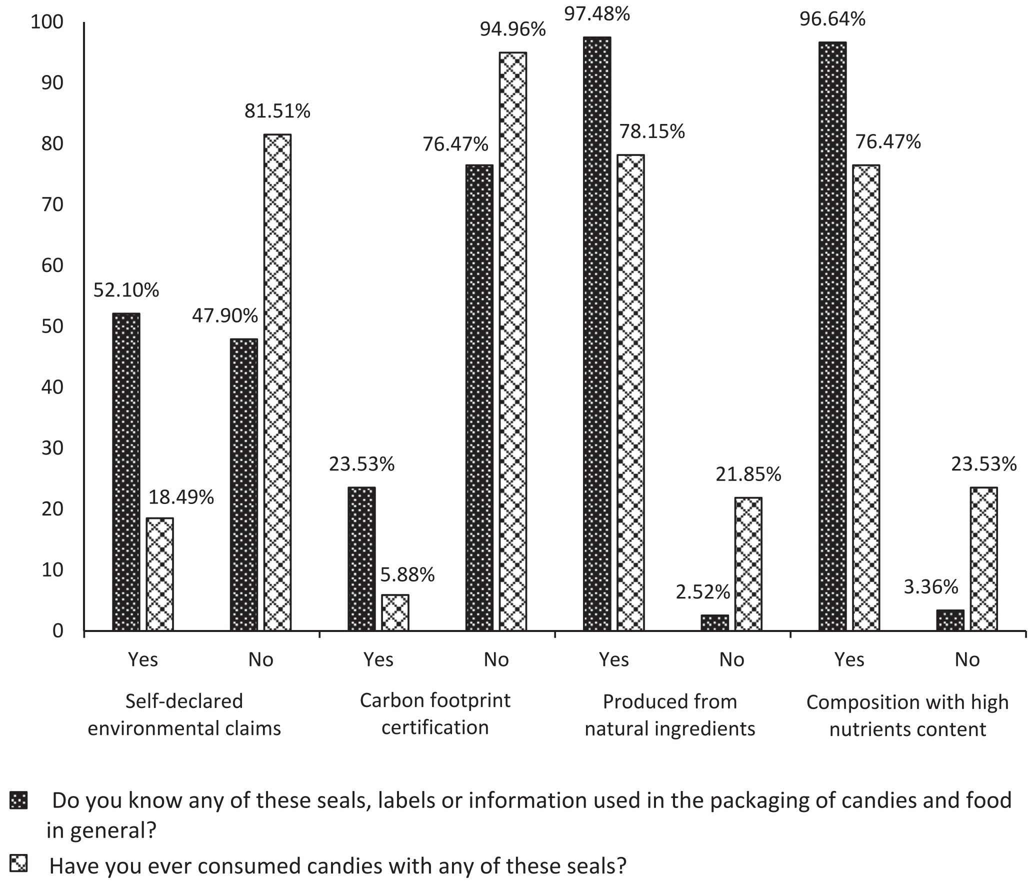

Fig. 3. Knowledge and frequency of consumption of candy with seals, labels or information on the packaging.

Food and Drug Administration (FDA) suggested a higher daily intake (90 mg/day for adults) [42], and requires the food must contain 20% or more of the reference daily intake of the substance necessary to achieve the claimed effect for the regulation of health claim "high content" on the label [43].

Considering the candies serving sizes indicated by FDA as 15 g of candy [44], the CSC serving offers an ascorbic acid content 1.22 times the daily intake recommended by FDA, which makes it possible to appoint claims of healthiness on the candy label.

Polyphenolics are a wide group of organic compounds with great interest in nutrition and human health due to their antioxidant properties and protection effects against certain cancers and diseases [45]. In food processing, they are subjected to degradation to oxygen, light, high temperatures, enzymes, metal ions and possible associations with other organic components [46].

The regulation for polyphenols consumption is challenged to the variety of substances and their contents in foods, shelf stability and proven scientific evidences of the health effects. For these reasons FDA have no regulatory recommendations yet for phenolic claims to food labels [45]. According to literature the phenolic compounds daily intake is estimated between 150 mg and 1 g/day [47]. CSC presented 3.3 times more phenolic compounds than HC. According to polyphenolic averages of the foods richest in antioxidant listed by Pérez-Jiménez et al. [48], CSC have a high phenolic content per candy gram. The possibility of appointment of health claims on the label, however, must be better evaluated according to legislation.

Anthocyanins are the main phenolic compounds in strawberry fruit [49], which stability during food processing is influenced by oxygen, pH, enzymes, light and metal ions presence [50]. There was no significant difference ($p < 0.05$) between the total anthocyanin content of the jellies, probably due to the high sugar content of HC recipe, which exercised protective effect on degradation reaction during HCP heating [16].

3.3.2. First sensory analysis: blind test

The results of the blinded sensory acceptance session are presented in Table 4. There was only significant difference ($p < 0.05$) between the samples for the texture parameter, wherein CSC showed higher average value. The acceptance scores for all sensory evaluated parameters were located between the term "indifferent" (mean 5.0) and I liked it moderately (mean 7.0), similar to the obtained for Avelar & Efraim [13] in the acceptance evaluation of cold-set model candies with no fruit pulp ingredients. According to the authors cold-set jellies and pectin jellies showed no sensory difference ($p < 0.05$) between any of the sensory attributes in the blind sensory test.

3.3.3. Purchase intention questionnaire

The questionnaire was applied between the first and second sensory sessions. The questionnaire reliability was determined with Cronbach's alpha coefficient and the obtained value was $\alpha = 0.80$. The consumers, which 33% were male and 67% were female aged from 18 to 34 years, answered about seals and their purchase intention in 16 questions as follows:

(i) Do you know any of these seals or labels or information used in packaging of candies and food in general? (Product with self-declared environmental claim; Product with carbon footprint certification; Product with identification of natural ingredients; Product with identification of high nutrients content)

(ii) Have you ever consumed candies with any of these labels (Product with self-declared environmental claim; Product with carbon footprint certification; Product with identification of natural ingredients; Product with identification of high nutrients content).

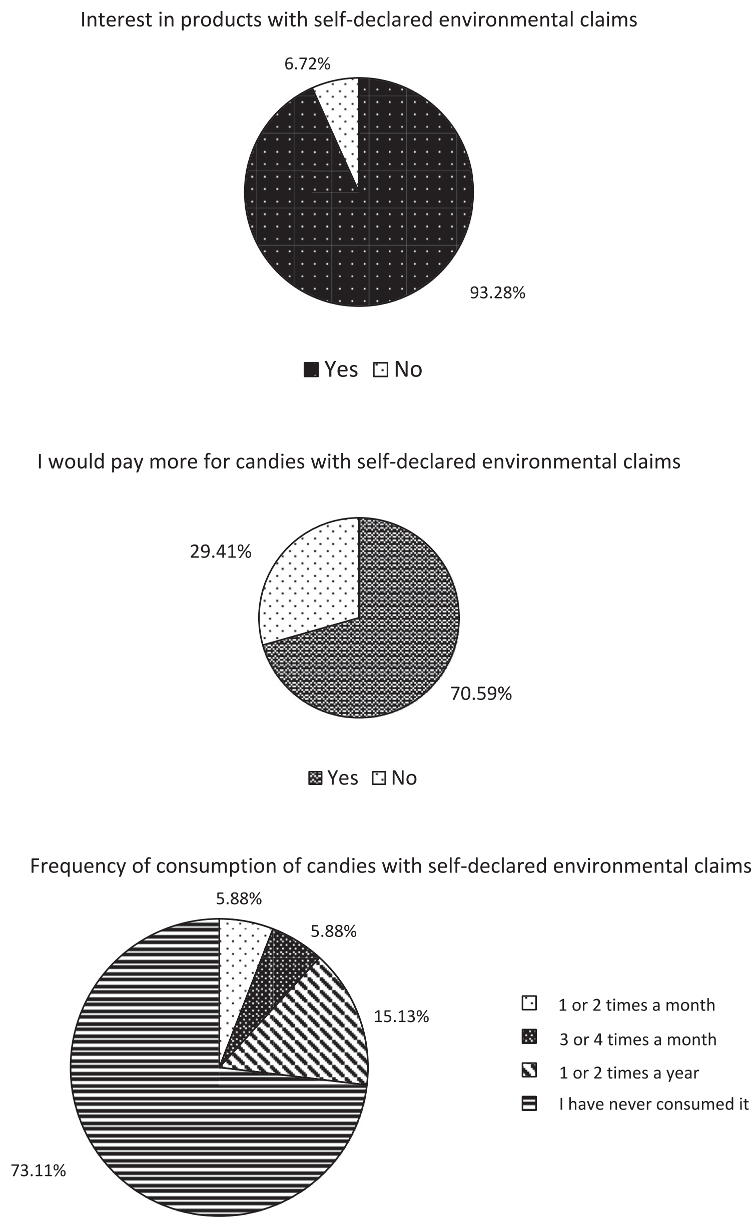

Fig. 4. Interest, willingness to pay and frequency of consumption of products with self-declared environmental claims.

According to consumers answer, the frequency of consumption is lower than the knowledge about candy with claims on packaging for all evaluated seals, labels and information (Fig. 3). Healthiness and naturalness claims were indicated as better known and more consumed than sustainable claims.

According to Ertz et al. [10], although the growing environmental labeling and exposing of consumer to pro-sustainable behavior, other factors such as price, brand, quality are still considered more important in consumer purchase. The limited knowledge of the consumer about specificities of environmental declarations, the difficulty to process sustainable claim and the multiple formats of environmental declarations used for comparable products are other limiting factors to the effectiveness of environmental labeling [51].

Healthiness claims are highly valued by consumers, however, the information on the labels receives varying attention according to the product, context and consumer interest. It is also indicated there are difficulties in assessing health claims for several reasons, such as terminology, presence of too much information, difficult in interpretation and the attempt to make diet-planning calculations [52].

(iii) Are you interested in products with self-declared environmental claim?
(iv) How often do you consume any candy with self-declared environmental claim?
(v) Would you pay more for a candy with self-declared environmental claim?

Most consumers showed interest in products with self-declared environmental claims (Fig. 4), however, more than 73% of them reported they have never consumed environmental labeled candies. When asked if they knew of any seal, label or information about self-declared environmental claims, almost half of consumers respond they did not (Fig. 3). The underinformed consumer combined with low market supply may justify the low consumption reported.

Over 70% of evaluators informed they would pay more for candies with sustainable environmental labelling. Other studies also pointed to consumer's high willingness to pay more for environmentally friendly products [10], and reported that more sustainable products are also considered to be more expensive [53].

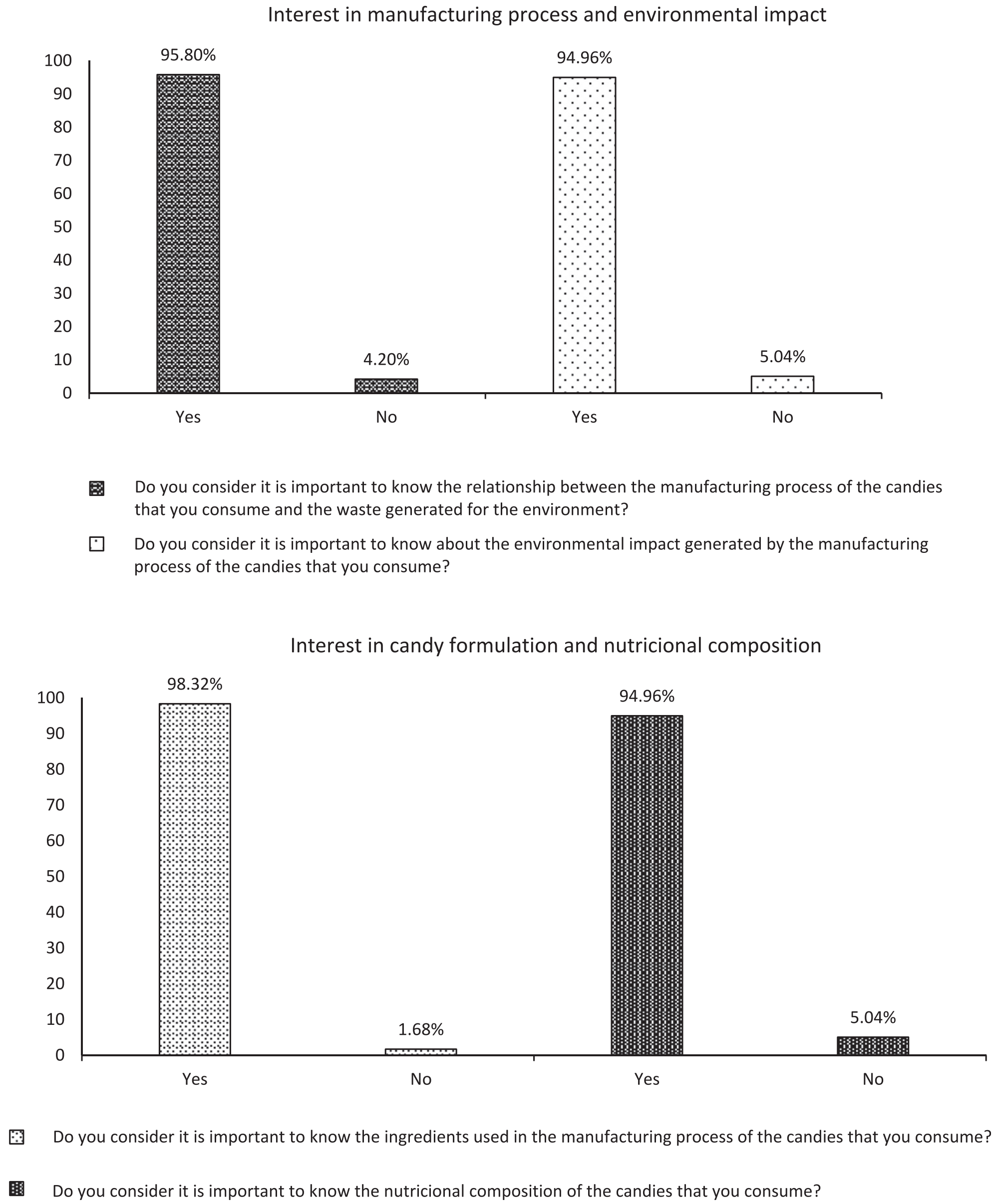

Fig. 5. Interest in candy formulation and nutritional composition and manufacturing process and environmental impact.

(vi) Do you consider important to know the relationship between manufacturing process, energy consumption and environmental waste of the candies you consume?
(vii) Do you consider important to know about the environmental impact generated by the manufacturing process of candies you consume?

The interest between candy manufacturing process and its environmental impacts and generated waste was indicated by most of consumers (about 95%) (Fig. 5). The environmental impact of food production and distribution and the food choices has been recognized by consumers and many studies have reported a growing interest in sustainable production and consumption in agriculture and food chain [54].

(viii) Are you interested in carbon footprint certified products?
(ix) How often do you consume any type of carbon footprint certified candy?
(x) Would you pay more for a certified carbon footprint candy?

The majority of consumers (about 76%) informed they didn't know about carbon footprint certification (Fig. 3) and almost 92% of them never consumed candies with these labeling (Fig. 6). However, the majority of evaluators showed interest and willingness to pay more for these labeled products.

The carbon footprint corresponds to greenhouse gas emissions during the life cycle of a product or service (from production, use/consumption to disposal) and it is calculated according to the greenhouse gases considered and the boundaries of the calculation (considered production stages with different possibilities of combinations of direct and indirect emissions according to the definitions of life cycle assessment) [55]. Carbon footprinting is not universally used and some countries adopt alternative methods to assess greenhouse gas emission [56].

According to executive and business trends studies, sustainable production of the main raw materials (organic, fair trade production) and packaging, and local supply of materials are considered the most important environmental tools adopted by the concept of sustainability in the confectionery sector, while the reduction of energy and gas emissions receive a lesser degree of importance [7].

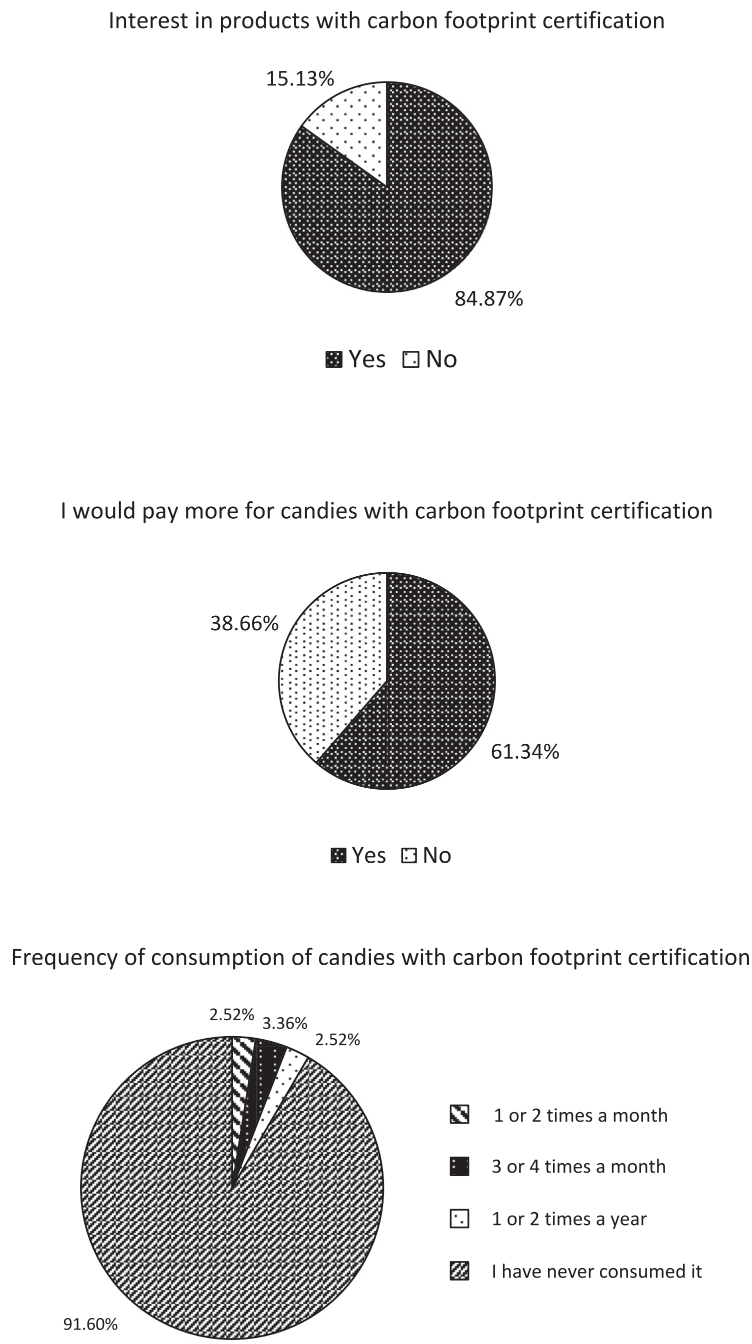

Fig. 6. Interest, willingness to pay and frequency of consumption of candies with carbon footprint certification.

(xi) Do you consider important to know about ingredients used to make the candies you consume?
(xii) Do you consider important to know about nutritional composition of the candies you consume?

When asked about formulation of candies and their nutritional facts most consumers reported interest (Fig. 5) and most confirmed they knew about nutritional seal, label or information (Fig. 3).

(xiii) How often do you consume any kind of candy with the claim "contains pulp/fruit juice in the formulation"?
(xiv) Would you pay more for a candy made from fruit pulp?

Almost 90% of consumers would pay more for candies produced from fruit ingredients and more than half of them showed high or moderate consumption of these products (Fig. 7).

Health perception is partly related to the process of assessing and understanding health claims, which are designed to provide useful information from manufacturers to consumers about concerning functions and benefits of the products or components [52]. Confectionery products with fruit ingredients are a growing segment of food market and supply consumers' desire for healthier, more authentic and natural foods. The consumer perceives fruits as ingredients with nutritional and functional value and, in this way, fruit flavored and colored candies are seen as higher quality products [57].

(xv) How often do you consume any kind of high nutrient candy?
(xvi) Would you pay more for high nutrient candy?

More than 80% of consumers have shown willingness to pay more for

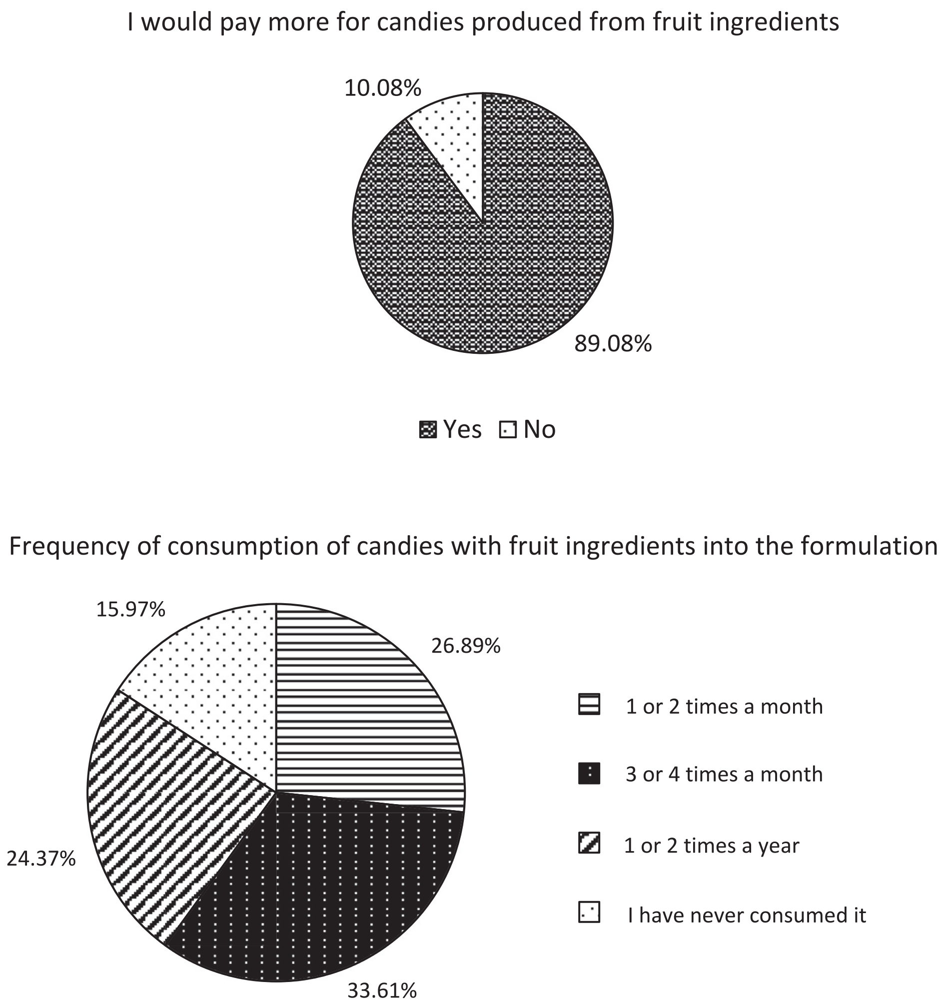

Fig. 7. Willingness to pay and frequency of consumption of candies with fruit ingredients.

candies with better nutritional composition. According to Ran et al. [58] many studies have shown that consumers are willing to pay more for products with nutritional information and many of them believe that nutrition labels help to interpret nutrition claims in the front of the packaging.

When asked about their frequency of consumption of candies with any high nutrient content, about half of them reported high or moderate consumption of products with these claims (Fig. 8).

3.3.4. Second sensory analysis session: test with samples identified with designation of environmental sustainability

In the second session consumers assessed the same candy samples, but this time they were identified with designation of environmental sustainability. According to results of item 3.2, CSC was labeled with the information "the manufacturing process of this jelly candy consumed 99% less energy and generated 300 times lower carbon dioxide emission for the environment than the conventional candy manufacturing process", while HC was identified with the information "this jelly candy was produced by the conventional manufacturing process".

After sample identification, there was a significant difference ($p < 0.05$) between the samples for texture, appearance and overall impression parameters, wherein HC showed the lower scores (Table 4).

The average score given to aroma parameter of HC in second session was significantly lower ($p < 0.05$) in relation to the average score of the blind test. CSC with designation of environmental sustainability showed higher values for appearance, texture and overall impression in relation to the scores reached in blind test, which means were relocated more next to term I liked it moderately (average score 7.0).

Factors such as positive attitudes, quality of life and environment are appointed by consumers of sustainable products as determinant in their purchase behavior and decision [51]. The observed changes when sustainability claims were attributed to the candy labels confirmed the interest of consumers in the environmental confectionery segment indicated in the questionnaire.

HC scores showed no significant difference ($p < 0.05$) between the sessions. The results highlight the influence of claims and labeling on sensory evaluation and reinforce the market potential of CSCP due to the increased acceptance of CSC.

Other studies have been reported the relation of environmental claims and food acceptance. In the confectionery sector, Silva et al. [32] verified the impact of sustainability labeling in sensory perception and purchase intention of chocolate consumers and concluded that acceptance scores increased, with no significant differences ($p < 0.05$), when sustainable labeling (organic and Rainforest Alliance certifications, and designation of origin) were informed, however, they observed for the same samples the sustainability claim can positively influence the consumer, inducing an initial interest to consumption of chocolates with sustainability labeling, but the continuous consumption depends more on the sensory expectations.

3.3.5. Third sensory analysis session: test with samples identified with environmental sustainability designation and health claims

In the third session, samples were identified with designation of environmental sustainability and healthiness (according to the results of

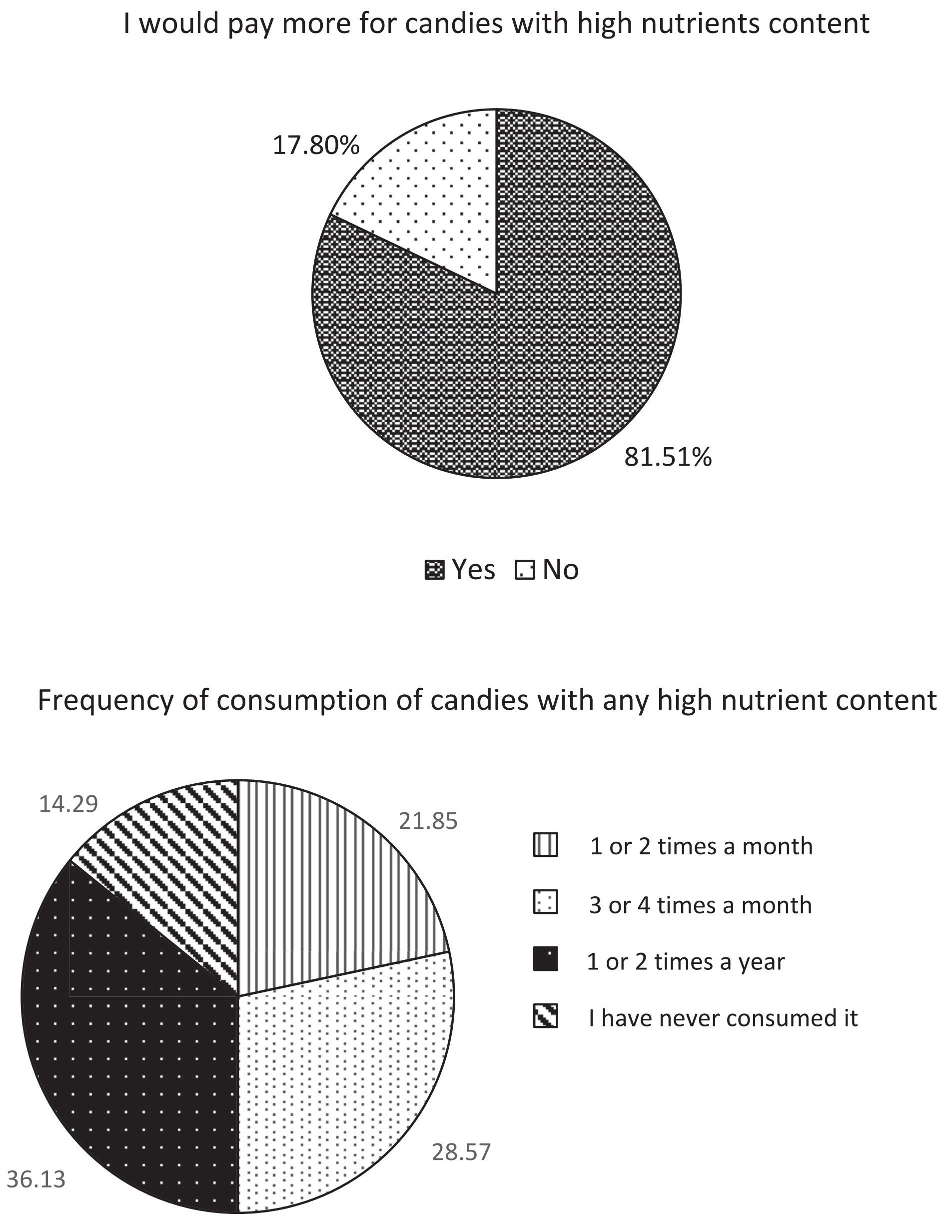

Fig. 8. Willingness to pay and frequency of consumption of candies with high nutrients content.

item 3.2 and 3.3.1) in order to verify the influence of health factors in the acceptance of sustainable labeled products. HC was identified with the information "this jelly candy was produced by the conventional manufacturing process", while CSC was labeled with the information "the manufacturing process of this jelly candy consumed less energy and emitted less carbon dioxide to the environment than the conventional candy manufacturing process. This manufacturing process has also conserved the nutrients in the strawberry pulp used as an ingredient of the candy, so this jelly candy has 22% more vitamin C and three times more total phenolic compounds than a jelly candy produced by the conventional method".

CSC score increased from the second to the third session when health claims were added to its sustainability designation, however, there was no significant difference ($p < 0.05$) between the sessions. A significant drop was verified for the acceptance of HC aroma, while the others sensory attributes did not present significant statistical changes.

Despite the increase of CSC acceptance scores, there was no significant difference between the second and third sessions. However, the statistically distinction to the first session was maintained for appearance, texture and global impression parameters. These results confirmed the health influence on consumer perception of food quality. Some studies have already reported health concerns and economic factors, in general, as the main drivers in the consumer's food choice, followed by environmental issues [59].

4. Conclusion

Despite the possibility of slightly higher ingredient costs the cold-set gelation technique using alginate/pectin mixtures showed great sustainable potential for the jelly candy processing industry due to the lower energy consumption and CO_2 emissions than the conventional candy manufacturing in both evaluated scales. In addition, the bioactive compounds content (ascorbic acid and total phenolic content) of the strawberry juice concentrate used as raw material were better maintained in cold-set jellies than in the pectin jellies.

The results of the questionnaire informed the consumer is very interested and willing to pay for products labeled with environmental and health claims. However, the knowledge about the sustainable claims and the consumption of this product segment are very low, which indicates the importance of the industry offering more options and helping the consumer to better understand sustainable food labelling.

A positive influence on consumer acceptance was observed when environmental sustainability and health labels were informed, increasing the sensory scores of the cold-set candy. This study confirmed the feasibility and market potential of cold-set jelly candy manufacturing against the growing food trend of environmental sustainability and healthiness.

Declarations of interest

The authors have no competing interests to declare about the manuscript entitled "Sustainable performance of cold-set gelation in the confectionery manufacturing and its effects on perception of sensory quality of jelly candies" submitted for publication in the Cleaner Engineering and Technology Journal.

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References

[1] Board, Eiri, 2012. Hand Book of Confectionery with Formulations. Engineers India Research Institute, New Delhi.
[2] Coyle, S.J., 2007. Cooking equipment for jelly candy. Manuf. Confect. (MC) 99, 36–42.
[3] Hartel, R.W., 2018. Jellies, gummies and licorices. In: Hartel, R.W., Elbe, J.H.V., Hofberger, R. (Eds.), Confectionery Science and Technology. Springer International Publishing, Cham, pp. 329–360. https://doi.org/10.1007/978-3-319-61742-8.
[4] Confectionery News, 2019. Organic Candy: the Future of Confectionery, Says New Report. https://www.confectionerynews.com/Article/2007/08/08/Organic-candy-the-future-of-confectionery-says-new-report (accessed 02 April 2020).
[5] Montenegro, F.M., Luccas, V., 2014. Macro trends in the bakery and confectionery sectors [*In Portuguese*]. In: Queiroz, G.C., Rego, R.A., Jardim, D.C.P. (Eds.), Brasil Bakery & Confectionery Trends 2020. ITAL, Campinas, pp. 59–71.
[6] Mongia, G., 2014. Fruit ingredients in confectionery applications. Manuf. Confect. (MC) 94, 73–82.
[7] Queiroz, G.C., 2014. Sustainability and transparency [*in Portuguese*]. In: Queiroz, G.C., Rego, R.A., Jardim, D.C.P. (Eds.), Brasil Bakery & Confectionery Trends 2020. ITAL, Campinas, pp. 232–257.
[8] FDA. Food and Drug Administration, 2013. Guidance for Industry: Food Labeling Guide. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-food-labeling-guide (accessed 03 April 2020).
[9] Castka, P., Corbett, C.J., 2015. Management systems Standards: diffusion, impact and governance of ISO 9000, ISO 14000, and other management Standards, foundations and trends in technology. Infor. Operations Manage. 7, 161–379. https://doi.org/10.1561/0200000042.
[10] Ertz, M., François, J., Durif, F., 2017. How consumers react to environmental information: an experimental study. J. Int. Consum. Market. 29, 162–178. https://doi.org/10.1080/08961530.2016.1273813.
[11] Iso 14021, 2012. Environmental labels and declarations Self-declared environmental claims (Type II environmental labelling). http://www.iso.org/iso/catalogue_detail?csnumber=23146 (accessed 03 April 2020).
[12] Kaenzig, J., Wüstenhagen, R., 2009. The effect of life cycle cost information on consumer investment decisions regarding eco-innovation. J. Ind. Ecol. 14, 121–136. https://doi.org/10.1111/j.1530-9290.2009.00195.x.
[13] Avelar, M.H.M., Efraim, P., 2020. Alginate/pectin cold-set gelation as a potential sustainable method for jelly candy production. LWT–Food Sci. Technol. 123. https://doi.org/10.1016/j.lwt.2020.109119.
[14] Bolder, S.G., Hendrickx, H., Sagis, L., Van der Linden, E., 2006. Ca2+-induced cold set gelation of whey protein isolate fibrils. Appl. Rheol. 16, 258–264. https://doi.org/10.1515/arh-2006-0018.
[15] Walkenström, P., Kidman, S., Hermansson, A.M., Rasmussen, P.B., Hoegh, L., 2003. Microstructure and rheological behaviour of alginate/pectin mixed gels. Food Hydrocolloids 17, 593–603. https://doi.org/10.1016/s0268-005x(02)00119-4.
[16] Avelar, M.H.M., Lima, L.N., Efraim, P., 2020. Maintenance of fruit bioactive compounds in jelly candy manufacturing by alginate/pectin cold-set gelation. J. Food Process. Technol. 11, 1–11. https://doi.org/10.35248/2157-7110.20.11.826.
[17] Aigroup, 2019. Energy reduction factsheet: saving energy in the confectionery manufacturing industry. In: http://cdn.aigroup.com.au/Environment/21_Food_Processing_Confectionery_Manufacturing_Energy_Reduction_Factsheet.pdf (accessed 03 April 2020).
[18] Chala, G., Abd Aziz, A., Hagos, F., 2018. Natural gas engine technologies: challenges and energy sustainability issue. Energies 11, 2934. https://doi.org/10.3390/en11112934.
[19] Davis, S.J., Peters, G.P., Caldeira, K., 2011. The supply chain of CO2 emissions. Proc. Natl. Acad. Sci. Unit. States Am. 108, 18554–18559. https://doi.org/10.1073/pnas.1107409108.
[20] Wojdalski, J., Grochowicz, J., Dróżdż, B., Bartoszewska, K., Zdanowska, P., Kupczyk, A., Ekielski, A., Florczak, I., Hasny, A., Wójcik, G., 2015. Energy efficiency of a confectionery plant – case study. J. Food Eng. 146, 182–191. https://doi.org/10.1016/j.jfoodeng.2014.08.019.
[21] Usda, 2020. Sugar and sweeteners yearbook tables. https://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables/ (acessed 20 August 2020).
[22] Sufferling, K., 2007. Gelatin gummies and pectin jellies. Manuf. Confect. (MC) 87, 43–50.
[23] Diaz, N., Redelsheimer, E., Dornfeld, D., 2011. Energy consumption characterization and reduction strategies for milling machine tool use. In: Hesselbach, J., Herrmann, C. (Eds.), Glocalized Solutions for Sustainability in Manufacturing. Springer., Heidelberg, pp. 263–267. Berlin.
[24] Eletrobrás, 2005. Energy Efficiency in Steam Use. Eletrobrás, Rio de Janeiro, p. 196 [*In Portuguese*].
[25] Petrobrás, 2013. Liquefied petroleum gas [*In Portuguese*]. http://sites.petrobras.com.br/minisite/assistenciatecnica/public/downloads/manual-tecnico-gas-liquefeito-petrobras-assistencia-tecnica-petrobras.pdf (accessed 07 April 2020).
[26] Mctic. Ministry of Science, Technology, Innovations and Communications, 2018. Dispatch analysis method [*In Portuguese*]. https://www.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/textogeral/emissao_despacho.html (accessed 07 April 2020).
[27] Mctic. Ministry of Science, Technology, Innovations and Communications, 2014. Annual estimates of greenhouse gas emissions in Brazil [*In Portuguese*]. http://sirene.mctic.gov.br/portal/export/sites/sirene/backend/galeria/arquivos/2018/10/11/Estimativas_2ed.pdf (Accessed 07 April 2020).
[28] Cheftel, H., Pigeaud, M.L., 1936. Estimation of ascorbic acid (vitamin C) by titration. Nature 138. https://doi.org/10.1038/138799b0, 799–799.
[29] Singleton, V.L., Othofer, R., Lamuela-Raventos, R.M., 1999. Analysis of total phenols and others oxidation substrates and antioxidants by folin-ciocalteau reagent. Meth. Enzimol. 299, 152–178. https://doi.org/10.1016/S0076-6879(99)99017-1.
[30] Tonutare, T., Moor, U.L., Szajdak, L., 2014. Strawberry anthocyanin determination by pH differential spectroscopic method – how to get true results? Acta Sci. Polonorum Hortorum Cultus 13, 35–47.
[31] Stone, H., Sidel, J.L., 2004. Sensory Evaluation Practices, third ed. Elsevier, Amsterdam, p. 377.
[32] Silva, A.R.A., Bioto, A.S., Efraim, P., Queiroz, G.C., 2017. Impact of sustainability labeling in the perception of sensory quality and purchase intention of chocolate consumers. J. Clean. Prod. 141, 11–21. https://doi.org/10.1016/j.jclepro.2016.09.024.
[33] Matthiensen, A., 2011. Use of Cronbach's alpha coefficient in questionnaire assessments *[in Portuguese]*. https://www.infoteca.cnptia.embrapa.br/bitstream/doc/936813/1/DOC482011ID112.pdf (accessed 07 April 2020).
[34] Businesswire, 2020. Correcting and Replacing Sugar Confectionery Market - Global Forecast and Opportunity Assessment by Technavio. https://www.businesswire.com/news/home/20170614006004/en/CORRECTING-REPLACING-Sugar-Confectionery-Market—Global (accessed 18 August 2020).
[35] Abicab, 2020. Candies & gums: production, apparent consumption, export and import in volume *[in Portuguese]*. http://clientes.focoimg.com.br/abicab/storage/app/public/editor/15918888235ee24bb72f99f.pdf (accessed 20 August 2020).
[36] Nilsson, K., Sund, V., Floren, B., 2011. The Environmental Impact of the Consumption of Sweets, Crisps and Soft Drinks. Nordic Council of Ministers, Copenhagen.
[37] Miah, J., 2018. From Factory to Supply Chain: Reducing Environmental Impacts of Confectionery Manufacturing Using Heat Integration and Life Cycle Assessment. University of Surrey, Guildford.
[38] Jou, C.-J.G., Wu, C.-R., Lee, C.-L., 2010. Reduction of energy cost and CO2 emission for the furnace using energy recovered from waste tail-gas. Energy 35, 1232–1236. https://doi.org/10.1016/j.energy.2009.11.002.
[39] Naidu, K.A., 2003. Vitamin C in human health and disease is still a mystery? An overview. Nutr. J. 2 https://doi.org/10.1186/1475-2891-2-7.
[40] Uddin, M., Hawlader, M.N.A., Ding, L., Mujumdar, A., 2002. Degradation of ascorbic acid in dried guava during storage. J. Food Eng. 51, 21–26. https://doi.org/10.1016/s0260-8774(01)00031-0.
[41] Fao. Food and Agriculture Organization, 2001. Human vitamin and mineral requirements. http://www.fao.org/3/a-y2809e.pdf (accessed 03 April 2020).
[42] Fda. Food and Drug Administration, 2020. Frequently asked questions for industry on nutrition facts labeling requirements. https://www.fda.gov/media/99069/download (accessed 03 April 2020).
[43] Fda. Food and Drug Administration, 2009. Guidance for industry: evidence-based review system for the scientific evaluation of health claims. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-evidence-based-review-system-scientific-evaluation-health-claims (accessed 03 April 2020).
[44] Fda. Food and Drug Administration, 2018. Food labeling: serving sizes of foods that can reasonably Be consumed at one eating occasion; dual-column labeling;

updating, modifying, and establishing certain reference amounts customarily consumed; serving size for breath mints; and technical amendments: guidance for industry small entity compliance guide. https://www.fda.gov/media/111144/download (accessed 03 April 2020).
[45] Cory, H., Passarelli, S., Szeto, J., Tamez, M., Mattei, J., 2018. The role of polyphenols in human health and food systems: a mini-review. Frontiers in Nutrition 5, 1–9. https://doi.org/10.3389/fnut.2018.00087.
[46] Volf, I., Ignat, I., Neamtu, M., Popa, V., 2014. Thermal stability, antioxidant activity, and photo-oxidation of natural polyphenols. Chem. Pap. 68, 1–9. https://doi.org/10.2478/s11696-013-0417-6.
[47] Tresserra-Rimbau, A., Medina-Remón, A., Pérez-Jiménez, J., Martínez-González, M.A., Covas, M.I., Corella, D., Salas-Salvadó, J., Gómez-Gracia, E., Lapetra, J., Arós, F., Fiol, M., Ros, E., Serra-Majem, L., Pintó, X., Muñoz, M.A., Saez, G.T., Ruiz-Gutiérrez, V., Warnberg, J., Estruch, R., Lamuela-Raventós, R.M., 2013. Dietary intake and major food sources of polyphenols in a Spanish population at high cardiovascular risk: the PREDIMED study. Nutr. Metabol. Cardiovasc. Dis. 23, 953–959. https://doi.org/10.1016/j.numecd.2012.10.008.
[48] Pérez-Jiménez, J., Neveu, V., Vos, F., Scalbert, A., 2010. Identification of the 100 richest dietary sources of polyphenols: an application of the Phenol-Explorer database. Eur. J. Clin. Nutr. 64, S112–S120. https://doi.org/10.1038/ejcn.2010.221.
[49] Tulipani, S., Mezzetti, B., Capocasa, F., Bompadre, S., Beekwilder, J., de Vos, C.H.R., Capanoglu, E., Bovy, A., Battino, M., 2008. Antioxidants, phenolic compounds, and nutritional quality of different strawberry genotypes. J. Agric. Food Chem. 56, 696–704. https://doi.org/10.1021/jf0719959.
[50] Patras, A., Brunton, N.P., O'Donnell, C., Tiwari, B.K., 2010. Effect of thermal processing on anthocyanin stability in foods; mechanisms and kinetics of degradation. Trends Food Sci. Technol. 21, 3–11. https://doi.org/10.1016/j.tifs.2009.07.004.
[51] Leire, C., Thidell, Å., 2005. Product-related environmental information to guide consumer purchases – a review and analysis of research on perceptions, understanding and use among Nordic consumers. J. Clean. Prod. 13, 1061–1070. https://doi.org/10.1016/j.jclepro.2004.12.004.
[52] Nocella, G., Kennedy, O., 2012. Food health claims – what consumers understand. Food Pol. 37, 571–580. https://doi.org/10.1016/j.foodpol.2012.06.001.
[53] Aschemann-Witzel, J., 2015. Consumer perception and trends about health and sustainability: trade-offs and synergies of two pivotal issues. Curr. Opinion Food Sci. 3, 6–10. https://doi.org/10.1016/j.cofs.2014.08.002.
[54] Vermeir, I., Verbeke, W., 2006. Sustainable food consumption: exploring the consumer "attitude – behavioral intention" gap. J. Agric. Environ. Ethics 19, 169–194. https://doi.org/10.1007/s10806-005-5485-3.
[55] Leach, A.M., Emery, K.A., Gephart, J., Davis, K.F., Erisman, J.W., Leip, A., Pace, M.L., D'Odorico, P., Carr, J., Noll, L.C., Castner, E., Galloway, J.N., 2016. Environmental impact food labels combining carbon, nitrogen, and water footprints. Food Pol. 61, 213–223. https://doi.org/10.1016/j.foodpol.2016.03.006.
[56] Pattara, C., Russo, C., Antrodicchia, V., Cichelli, A., 2016. Carbon footprint as an instrument for enhancing food quality: overview of the wine, olive oil and cereals sectors. J. Sci. Food Agric. 97, 396–410. https://doi.org/10.1002/jsfa.7911.
[57] Queiroz, M.B., Nabeshima, E.H., 2014. Naturalness and authenticity [*in Portuguese*]. In: Queiroz, G.C., Rego, R.A., Jardim, D.C.P. (Eds.), Brasil Bakery & Confectionery Trends 2020. ITAL, Campinas, pp. 159–195.
[58] Ran, T., Yue, C., Rihn, A., 2016. Does nutrition information contribute to grocery shoppers' willingness to pay? J. Food Prod. Market. 23, 591–608. https://doi.org/10.1080/10454446.2015.1048027.
[59] Hartikainen, H., Roininen, T., Katajajuuri, J.-M., Pulkkinen, H., 2014. Finnish consumer perceptions of carbon footprints and carbon labelling of food products. J. Clean. Prod. 73, 285–293. https://doi.org/10.1016/j.jclepro.2013.09.018.