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A N I N T E R N A T I O N A L J O U R N A L

Tropical Fruit Pulps: Processing, Product Standardization and Main Control Parameters for Quality Assurance

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ABSTRACT

Fruit pulp is the most basic food product obtained from fresh fruit processing. Fruit pulps can be cold stored for long periods of time, but they also can be used to fabricate juices, ice creams, sweets, jellies and yogurts. The exploitation of tropical fruits has leveraged the entire Brazilian fruit pulp sector due mainly to the high acceptance of their organoleptic properties and remarkable nutritional facts. However, several works published in the last decades have pointed out unfavorable conditions regarding the consumption of tropical fruit pulps. This negative scenario has been associated with unsatisfactory physico-chemical and microbiological parameters of fruits pulps as outcomes of little knowledge and improper management within the fruit pulp industry. There are protocols for delineating specific identity and quality standards (IQSs) and standardized good manufacturing practices (GMP) for fruit pulps, which also embrace standard operating procedures (SOPs) and hazard analysis and critical control points (HACCP), although this latter is not considered mandatory by the Brazilian legislation. Unfortunately, the lack of skilled labor, along with failures in complying established protocols have impaired quality of fruit pulps. It has been necessary to collect all information available with the aim to identify the most important hazards within fruit pulp processing lines. Standardizing methods and practices within the Brazilian fruit pulp industry would assurance high quality status to tropical fruit pulps and the commercial growth of this vegetal product towards international markets.

Key words: processing, standards of identity and quality, vegetable product, food safety.

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INTRODUCTION

Quality is increasingly referred to as an important element within the food industry. The growing demand for high quality food products has disseminated the use of quality management tools to meet expectations of consumers and market throughout the world, and also to manufacture safe products, thereby reducing costs and production losses [1].

Consumer expectations are much more demanding than in the past. Nowadays, there are major concerns related to food safety (pathogenic microorganisms and harmful substances) and food quality that involve various aspects, from the entire production chain up to fair labor payments and environmental impacts to soil and water. The rapidly increasing demand for fresh fruits has reflected changes in consumer preferences for healthier foods, which should also be produced through environmentally friendly processes [2].

Brazil is an essentially agricultural country with a huge potential for cultivating traditional and exotic fruits. Fruit pulp is the most basic product obtained from fresh fruit processing, although its production and conservation have not been correctly accomplished in Brazil. In the last decades, numerous studies have pointed out the technological inadequacy of Brazilian fruit pulps for human consumption, which reflect lack of qualified labor, standardized processing methods and good manufacturing practices (GMPs) in small and medium-sized companies. These aspects are considered important because they guarantee the adequate quality control on raw materials and processed foods.

This review article gathers the major shortcomings of quality control within the Brazilian fruit pulp production sector. Moreover, the most important aspects for obtaining innocuous and nutritious fruit pulps to meet consumer expectations are also outlined.

FRUIT MARKET AND FRUIT PULP PRODUCTION

Brazil produces a wide diversity of tropical, subtropical and temperate fruits due to its continental dimensions and variety of climates. Brazil also presents regional productions specialized in certain types of fruits [3].

Brazil is the third world's largest fruit producer with an annual production of 42,416 million tons in 2012, after China and India. Unprocessed fresh fruits accounts for 53% of the total commercial Brazilian fruit production, of which 3% is used to supply the international market. Of the total amount of fresh fruits 47% is processed by the national food industry. This means that 71% of total Brazilian fruit production is consumed by the domestic market, while the remaining 29% is exported to abroad [4].

European Union and United States are the main purchasers of Brazilian fruits and their derivative products. According to the Brazilian Fruit Institute (IBRAF), 759,400 and 2,149,800 tons of fresh and processed fruits, respectively, were exported in 2010, with focus on tropical fruits, whose sensorial acceptance and production have been continuously increasing in the past two decades.

Pulp and juice processing are important agro-industrial activities for the food production sector as they add economic value to fruits, avoid fruit wasting and minimize losses during commercialization of unprocessed fresh fruits. Pulp and juice processing also constitute an alternative way by which fruit growers sell their products.

One advantage of industrializing fruit pulp is the consumption of fruits native to particular regions throughout the country, some of which being highly coveted on the international market [5]. Fruit pulps could also supply the food industry for producing juices, ice creams, candies and confectionery and dairy products such as yogurts [6]. The markets of concentrated juice and pulp are notably relevant because they seek to attract consumers fundamentally by the idea of fruit nutritional value preservation [7].

Preserving highly perishable fruits constitute a big challenge for agro-industries. These industries have been focused mainly on processing methods that conserve the physical structure and the nutritional and sensory attributes of fruits. Agro-industries have also been focused on expanding the consumer market of fruit pulps. Nevertheless, the lack of standard procedures within the fruit processing sector, from the farm to the final consumer, is among the major shortcomings to be overcome by fruit pulp agro-industries [8].

FRUIT PULP PROCESSING AND ASPECTS FOR QUALITY MAINTENANCE

Postharvest loss is an important shortcoming for fruit pulp production because certain fruits remain alive after they are harvested. This implies that specific procedures and recover methods must be adopted in order to extend fruit shelf-life and use surplus production. These measures are taken according to the fruit type, which helps defining the best ways to handle fresh fruits during harvest, transportation, storage and commercialization.

Climacteric fruits, such as peach, apple, mango, guava, passion fruit, among many others, can be harvested when they reach the physiological maturation point, i.e., when they reach an ideal size and format, even if they are not ready for consumption. In this sense, climacteric fruits are suitable for industrialization because they provide higher uniformity in the maturation process. On the other hand, non-climacteric fruits, such as orange, lemon, pineapple and grape, do not have the ability to reach attributes that are typical of ripe fruits (sweetness, color, and acidity) after harvesting. In this case, non-climacteric fruits must be harvested only when they are completely ripened.

Consumption of fruit pulp and juice is rising continuously due to the consumer preference for healthy eating habits. Advances on food technology have enabled successful fruit processing and pulp freezing storage in appropriate packages within the food industry. Commercialization of frozen fruit pulps also make possible consumption of fruits little known, which have already attracted interest from the international market, especially those from Cerrado, North and Northeast regions of Brazil [9].

Fruit pulp production line normally embraces the following steps: reception, weighing, pre-selection, washing and sanitization, pulping, packaging and freezing. In general, fruits are frozen when there is insufficient amount of fruit to be pulp, whereas unripe fruits are cooled after the washing/sanitization step. The flowchart in Figure 1 illustrates the overall process that should be adopted in order to manufacture good quality fruit pulps. Pre-selection/selection of fruits, washing and sanitization, cooling or freezing are the most important steps and must be efficiently performed [10].

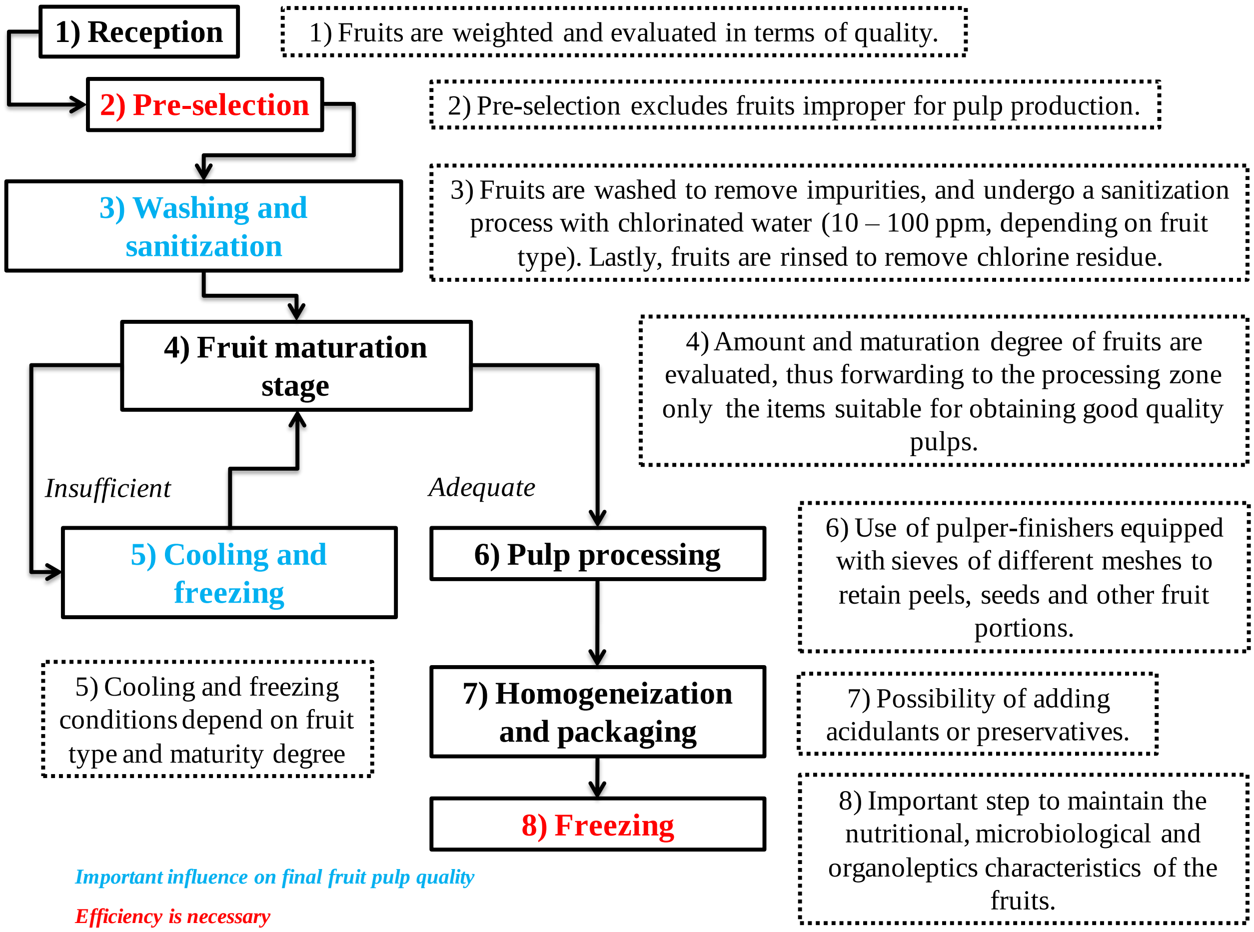

Figure 1 - Fruit pulp processing flowchart.

For small and micro-sized agro-industries, harvesting fruits at the maturation point is the most recommended practice. The maturation point is commonly referred to as firm ripe or "turning", which means that fruits will rapidly attain the maturation degree suitable for processing. A number of parameters defined by law, including physiological maturation (if the fruit is climacteric or non-climacteric), pH, soluble solid content (°Brix) and acidity, should be determined still in field in order to harvest fruits with characteristics apposite for processing [11,12]. After harvesting, fruits must be suitably transported and handled to avoid mechanical injuries, heating and accumulation of metabolites [13].

The reception step consists in receiving, weighing and pre-selecting fruits, thus avoiding entrance of unsuitable fruits within the processing line and improving the final product quality. Fruit pre-selection should be conducted efficiently in order to remove physically damaged, dirty or completely decayed fruits which could spoil the final product.

Storing insufficient amounts of ripe fruits for processing should be preferably done after the sanitization step. Cleaned fruits can be organized into plastic boxes and stored under refrigeration or in ventilated and little humid areas for preventing rodent attacks and proliferation of molds and insects.

Cleaning and sanitization are different steps although they are fundamental for removing microbial load from fruits. Cleaning usually consists in washing fruits with water to eliminate impurities and part of the microbial load brought from plantations, whereas sanitization is generally carried out with chlorine-based substances.

Sodium hypochlorite is one of the most popular chlorine-based sanitizers whose antimicrobial activity is rather widespread [14,15]. When sodium hypochlorite is dissolved in cold water, it reacts to form hypochlorous acid, which is a strong oxidizing agent that is effective against foodborne pathogens (*S. aureus, L. monocytogenes* and *E. coli*). Hypochlorous acid serves to disinfect surfaces, fruits and vegetables, by killing suspended and film-forming microorganisms [16-19].

Fruit immersion into sodium hypochlorite solution is usually performed for 15 min, using concentrations between 20 and 100 ppm to reduce the microbial load to permissible levels. Long-term usages of sodium hypochlorite solution should be previously tested due to the time-dependent chlorine degradation. Fruits must be subsequently rinsed in order to remove hypochlorite residue (Table 1).

Table 1 – Initial sodium hypochlorite concentration and residual chlorine concentration after sanitization (15 min) of some tropical fruits.

Fruit	Initial Concentration (ppm)	Residual Concentration (ppm)
Pineapple	30	25
Acerola	90	20
Hog plum	70	10
Cashew	80	10
Guava	50	25
Soursop	20	10
Mango	50	20
Passion fruit	30	20
Umbu	80	10
Umbu-hog plum	80	10

Sodium hypochlorite is advantageous over various sanitizers due to its low cost, easy storage when produced *in situ*, disinfection efficiency similar to that of chlorine gas, and can remain at residual concentration. On the other hand, sodium hypochlorite is toxic and corrosive, especially at high concentrations. It also tends to decompose in contact with air, spreading chlorine gas which is toxic.

The chlorine antimicrobial activity efficiency is influenced by:

• **Presence of organic matter:** Organic materials such as food residue decrease the chlorine antimicrobial activity. Thus, fruits must be previously cleaned to attain a proper sanitization efficiency;

• C**hlorinated solution pH:** pH affects microbial activity. The highest chlorine antimicrobial activity occurs at pH 6.5 - 7.0 because hypochlorite is highly unstable at pH 4;

• Temperature: Sanitizers often exhibit synergistic effect with temperature. However, chlorinated compounds decompose into chlorine gas at elevated temperatures, in addition to increasing their corrosive potential over heating;

• **Concentration:** As aforementioned, chlorine levels of 20 and 200 ppm are used to sanitize fruits and processing, which must be washed afterwards to remove the chlorinated solution residue;

• **Contact time:** Fruit sanitization with sodium hypochlorite is efficiently attained within 30 min. Longer treatments should be avoided because the chlorine corrosive potential increases significantly over time [20].

The water used in the fruit sanitization step must present physical, chemical and microbiological qualities in consonance with the ordinance 2914 of December 12, 2011 of the Brazilian Ministry of Health. These quality aspects include absence of dirties and fecal coliforms and *Salmonella* (in 100 mL), reduced number of heterotrophic bacteria, appropriate pH and turbidity. Sanitization water must also contain sodium hypochlorite at concentrations between 0.2 - 2.0 ppm, or chlorine dioxide at a minimum level of 0.2 ppm throughout all water distribution system in order to warranty the use of disinfected water in fruit sanitization [21].

According to the ordinance CVS 6-99 of the Health Surveillance Center of São Paulo Secretary of Health, the chemicals and their final concentrations authorized for food sanitization are listed below:

- Sodium hypochlorite at 2.0 - 2.5%, to obtain concentrations from 100 to 250 ppm;
- Sodium hypochlorite at 1%, to obtain concentrations from 100 to 250 ppm;
- Organic chlorine at 100 - 250 ppm.

Controlling the sanitization process by proper adjustment of the active chlorine concentration is important to ensure not only elimination of microbial load, but also to preserve fruit organoleptic attributes. Sanitization of surfaces, machines and tools with chlorinated solutions 100 - 200 ppm and subsequent rinsing should also be performed before and after fruit pulp processing.

Fruits must be separated according to their maturation degree. Unripe fruits must be stored under adequate temperature and relative humidity in order to control the ripening process and extend their shelf-life. This preserves the physical and sensory characteristics of fruit pulps.

According to the ordinance CVS 6-99 of the Health Surveillance Center of São Paulo Secretary of Health, perishable food storage has to meet the following temperature criteria:

- Frozen foods: -18 ºC with tolerance of up to -12 ºC;
- Cooled foods: 6 - 10 ºC, or in conformity with supplier's specifications;
- Refrigerated: up to 6 ºC, with tolerance of 7 ºC.

Storage chamber temperature should be ideally monitored by charts displaying inferior and superior temperature limits (Figure 2). In this way, the storage chamber is operated most of the time within the permitted temperature range. Points that lie outside the limits can also be identified.

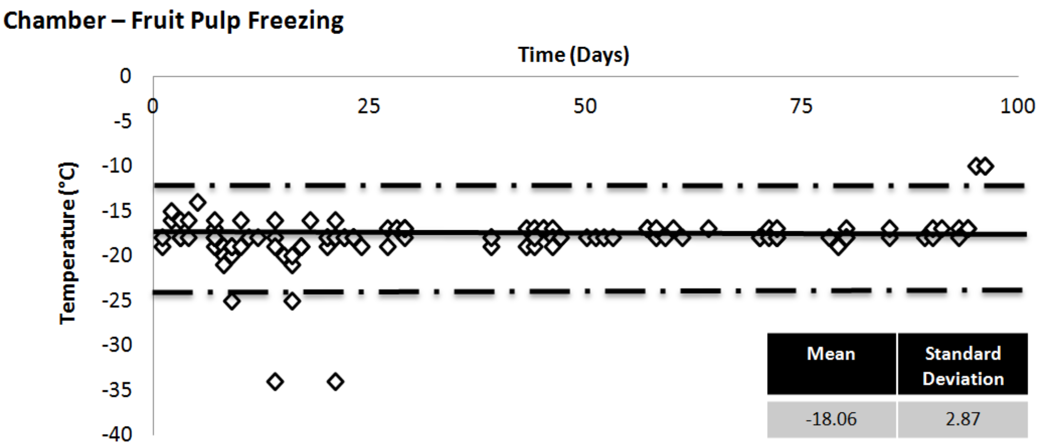

Figure 2 – Chamber temperature monitoring chart.

Fruit freezing must be performed as rapidly as possible in order to maintain the fresh fruit attributes. The usual freeze temperature range is between -12 and -23 °C. From chemical and technical points of view, the ideal temperature is -18 °C and this should be held constant throughout the freezing step. The cooling times to reach -5 °C and -18 °C should not be longer than 8 and 24 h, respectively [22].

Fruit pulp processing is carried out with the aid of pulper-finishers containing sieves with different apertures to separate peels, seeds and fibers from pulp. Fruit pulping should be performed continuously (all raw materials must be separated for continuous processing, while the packaging sector has to be prepared to receive the pulp) and rapidly, because the cooling and freezing times directly influence on the fruit pulp quality. Hand peeling, such as that used for pineapple and soursop, is another important aspect of pulp processing because food handlers contact directly internal portions of fruits. This requires maximum personal hygiene and sanitized premises. Hand peeling also constitutes a time-consuming additional stage of the fruit pulp production with high probability of microbial spoilage and fruit oxidation (nutrient and color losses).

The homogenization stage is ideally performed by coupling the pulper-finishers to the homogenization tank and packing machine, so that exposition of fruit pulp to light, air, and processing environment is efficiently avoided. Food preservatives are generally added to fruit pulps at the homogenization stage to increase consumer acceptance or extend their shelf-life.

The normative instruction No 01, 2000, of the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA) defines that fruit pulps used in beverage industrialization are permitted to contain chemical additives, such as acidulants (acidity regulators), synthetic preservatives, and natural colorants, at concentrations equivalent to those allowed for fruit juices, with some specific exceptions.

The use of food preservatives aims to prevent fruit pulps from oxidation and microbial spoilage. Citric acid and sodium benzoate are among the most used food additives; the first one is used as an acidulant in sufficient amounts, while the latter is used as a preservative at maximum concentration of 1 g per kg or L of product. These limiting concentrations are listed in the resolution RDC No. 8 March 6, 2013, which establishes food additives permitted in fruits, vegetables and mocotó jelly.

Acidulants are added to food products with the purpose of intensifying their sour attribute. Citric acid is the most used acidulant in the food industry due to:

- Versatile applications, including "*flavouring*" (taste and aroma) to synergy with antioxidant compounds, in addition to controlling pH.
- Easy obtaining (fermentation with *Aspergillus niger*).
- Relatively low cost [23].

Although citric acid is highly compatible with most fruits, its usage as an acidulant should not be generalized. Citric acid may affect fruit sensory attributes, for example, in the case of pineapple. Ascorbic acid is considered more suitable than citric acid for acerola, soursop and cashew. Lemon juice is recommended for pineapple and hog plum fruits. In the case of passion fruit, the use of acidulants is not recommended due to the high acidity of this fruit [24].

Benzoic acid and its derivatives, such as sodium benzoate, are efficient in controlling growth of yeasts and molds at pH range 2.5 - 4.0, over which they occur predominantly in a chemically dissociated form. Sodium benzoate is a microbiostatic agent that exhibits temporary activity on microorganisms. It is compatible with fruit pulps, whose shelf-life is no longer than 45 days, but for durable food products sodium benzoate must be used in conjunction with other antimicrobial agents. The maximum sodium benzoate concentration authorized in fruit juices and pulps is 1000 ppm, which is not deleterious to human health, being excreted as hippuric acid after reacting with glycine [25].

Fruit pulp quality inspection takes into account the standard microbiological and physico-chemical parameters for fruit pulps. Microbiological parameters are defined by product class (fruit-derived consumer goods, for instance), whereas physico-chemical parameters are specifically defined by fruit type because of the peculiar characteristics of each fruit [12].

In Brazil, microbiological quality of commercial fruit pulps is mainly legislated by the resolution RDC No 12, 2001, of ANVISA which approves technical regulation on the microbiological standards for foods [26] and the normative instruction No 12, 1999, of MAPA which legislates the quality parameters of fruit pulps [11]. The MAPA's normative instruction No 1, 2000, determines the main standardized physico-chemical parameters of fruit pulps with basis on acidity, total soluble solid content (°Brix), pH, total solids content, total natural sugar content, and vitamin C content. This normative instruction defines fruit pulp as a non-fermented, non-concentrated and undiluted product obtained from pulpy fruit crushing [12].

The microbial load in fruit-derived products is normally an outcome of raw material conditions and washing step efficiency, in addition to the hygienic-sanitary conditions of food handlers [27]. Microbiological parameters are important food quality aspects because they allow evaluating food products in relation to processing conditions, storage, distribution, shelf-life and risk to public health [28].

Reaching high fruit pulp quality standards requires effective hygienic conditions from the production stage until commercialization. This also involves control on raw materials, industrial processing, transport and storage. Inside a processing plant, there must exist proper maintenance of equipment, water supply network, sewage network and electricity, as well as a correct stock flux. Training and ongoing supervision of food handlers by competent professionals is also indispensable because all activities are always performed by a considerable number of employees [29].

Fruit pulp obtaining is a basic physical extraction process with possible addition of food preservatives and acidulants. Therefore, the final pulp quality will be highly dependent on the fresh fruit characteristics. In this context, fruit integrated production (FIP or PIF in portoghese) is a program that was developed in collaboration with MAPA to evaluate adequacy of fruit-derived products. FIP is based on four pillars: Production basis organization, system sustainability, and process and information monitoring (Figure 3). The main purpose of FIP is to monitor increases in the Brazilian fruit agribusiness exportation and Brazilian fruit quality. The application of natural resources with focus on environmental conservation and agriculture sustainability is the principal operation strategy of FIP. This has been implemented through systematic evaluation of fruit production with periodic monitoring, use of integrated pest management (IPM) techniques, reduction of pollutant inputs to ensure diversity and equilibrium to agro-ecosystems, and to ensure adequate and safe working conditions to employees [30].

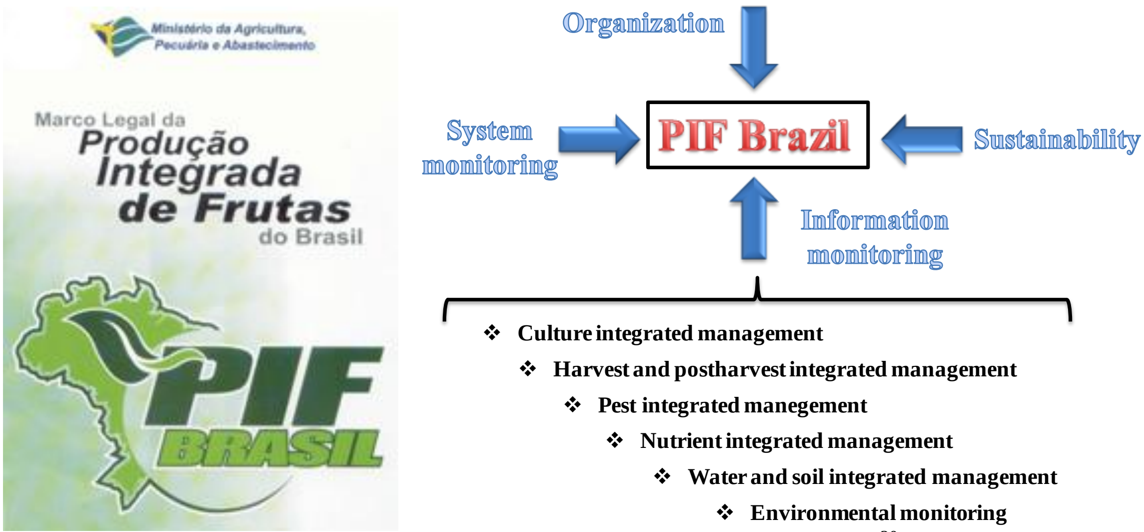

Figure 3- Fruit integrated production scheme. Source: Adapted from EMBRAPA [30].

Standard conformity seals containing numeric codes have served to validate food products as FIP, and also to track information on their origin and management procedures (pests, diseases, etc.). Consequently, there is a possibility of inspecting the conditions by which fruits were produced, transported, processed and packed, thus identifying fruit pulps since the production source until the final commercialization [8]. FIP program helps the food industry obtain good quality fruits suitable for pulp production.

IDENTITY AND QUALITY STANDARDS (IQSs) FOR FRUIT PULPS

The RDC No. 12, 2001, of ANVISA and the normative instructions (IN) No. 12, 1999 and IN No. 01, 2000, of MAPA are the main legislations on identity and quality standards (IQSs) of fruit pulps. The underlying purpose of an IQS is to protect consumers. Food IQSs can be used to prevent diseases transmission, restrict sale of fraudulent products and simplify purchase and sale of certain food products [31].

In relation to microbiological analyses, the ANVISA legislation DRC No. 12, 2001, recommends a limit of 10^2 fecal coliforms (MPN/mL) and absence of *Salmonella* in 25 g of pulp. The MAPA IN No. 12, 1999, recommends limits of 5.10^3 CFU/g for molds and yeast, and 1 NMP/g for fecal coliforms. The limit value of yeasts and molds for chemically conserved or thermally treated fruit pulps changes to 2.10^3 CFU/g according to the same legislation.

Regarding physico-chemical analyses of fruit pulps, including acidity, pH, °Brix, total solid content, total sugar content and vitamin C content, the Brazilian legislation establishes minimum required standards which depend on the fruit type [12]. Table 2 summarizes quality standards of some tropical fruits produced at the Brazilian northeast region that are widely accepted in the national market.

Table 2 – Identity and quality parameters (IQP) of tropical fruits.

Fruits	TSS (°Brix) 20°C	Acidity (g citric acid/100 g)	pH	Vitamin C (mg/100g)	Total natural sugars (g/100 g)	Total solids (g/100g)
Acerola	≥ 5.5	≥ 0.80	≥ 2.8	≥ 800.0	4.0 - 9.5	≥ 6.5
Pineapple	≥ 11.0	≥ 0.30	-	-	≤ 17.0	≥ 14.0
Cocoa	≥ 14.0	≥ 0.75	≥ 3.4	-	10.0 - 19.0	≥ 16.0
Hog plum	≥ 9.0	≥ 0.90	≥ 2.2	-	≤ 12.0	≥ 9.5
Cashew	≥ 10.0	≥ 0.30	≤ 4.6	≥ 80.0	≤ 15.0	≥ 10.5
Guava	≥ 7.0	≥ 0.40	≥ 3.5	≥ 40.0	≤ 15.0	≥ 9.0
Soursop	≥ 9.0	≥ 0.60	≥ 3.5	≥ 10.0	6.5 - 17.0	≥ 12.5
Papaya	≥ 10.0	≥ 0.17	≥ 4.0	-	≤ 14.0	≥ 10.5
Mango	≥ 11.0	≥ 0.32	3.3 - 4.5	-	≤ 17.0	≥ 14.0
Mangaba	≥ 8.0	≥ 0.70	≥ 2.8	-	≤ 8.5	≥ 10.0
Passion fruit	≥ 11.0	> 2.50	2.7 - 3.8	-	≤ 18.0	≥ 11.0
Melon	≥ 7.0	≥ 0.14	≥ 4.5	-	≤ 12.0	≥ 7.5
Pitanga	≥ 6.0	≥ 0.92	2.5 - 3.4	-	≤ 9.5	≥ 7.0

Source: MAPA [12].

It is worth mentioning that many tropical fruit pulps highly valued in the Brazilian market do not have identity and quality standards yet, for example umbu, tamarind, sapodilla, and genipap. This hinders the requirement for control parameters and quality adjustment for these fruit pulps.

Problems on physico-chemical standards of fruit pulps

Table 3 compares some physico-chemical data of tropical fruit pulps already published in literature. The largest discrepancies between the physico-chemical parameters and the decreed values are observed for total soluble solid content (°Brix), total titratable acidity (g citric acid/100 g) and vitamin C content.

The main variables affecting the total soluble solid content of fruit pulps are the rainfall regime during harvest season and fruit maturation degree. These natural problems indicate wrong cultivation or harvest management. They are also associated with poor quality raw materials and pulp dilution (water addition), which is a common practice justified by some producers as a way to improve the pulping step efficiency.

Table 3 – Summary of published studies on physico-chemical analysis of tropical fruit pulps.

Reference	Fruit	Place/Additional information	Main reported irregularities
31	Acerola, pineapple, hog plum and cashew	Campina Grande (PB), four brands were studied with 24 samples	There was disagreement in relation to the law in 44% of the samples, specifically TTA for hog plum, SST for acerola, cashew and total sugar content for all acerola samples.
10	Pineapple, acerola, hog plum, cashew, soursop, mango and passion fruit	Alagoas, samples from one brand	TSS and TS for mango, cashew and soursop pulps, TS for hog plum and acerola pulp (70% of all samples).
19	Pineapple, plum acerola, cashew, guava, soursop, mango, mangaba, passion fruit, pitanga and mandarin	Alagoas, samples from one brand but from 3 different lots	The most irregular samples were pineapple, plum, cashew, guava and passion fruit pulps, representing 45% of pulps unsuited for IQSs.
36	Pineapple, acerola, cocoa, guava	Itapetinga (BA), two brands were studied	All pulps were in conformity with IQSs.
37	Mango	Zona da Mata (MG), one brands were studied	None. All samples were in accordance with the law.
38	Acerola, passion fruit	Belo Horizonte (MG), pulp produced in laboratory from fruits purchased from central market	TTA for acerola pulps.
39	Hog plum, guava, mango and umbu	Reconcavo Baiano (BA), Pulps from four different brands were studies	TSS and vitamin C content of mango and guava pulps (around 15% of all samples).
40	Hog plum and mango	Teresina (PI), five brands were studied	Irregularities in 60% and 20% of hog plum pulp regarding TSS and TTA, respectively. Irregularities in 20% and 40% of mango pulp regarding moisture content and pH.
41	Acerola, hog plum and cashew	Ceará and Rio Grande do Norte states, 45 samples were studied	Many samples were not in accordance with the law, especially in terms of TSS (about 50% of samples), TTA (about 55% of samples) and vitamin C (25% of samples, mainly acerola pulps).
42	Acerola, hog plum and cashew	Pernambuco and Paraiba states, 71 samples were studied with about 45 % of the pulp industries located in both states	Irregularities mainly related to TSS, TTA and vitamin C content in 68.2% of hog plum pulps, 59.1% of cashew pulps and 40.7% of acerola pulps.
43	Acerola, cashew and passion fruit	Médio Norte (MT), four different brands were studies: two brands from Mato Grosso states and two brands from Bahia and Parana states.	TTA, TSS and TS of more than 50% of samples were below the values determined by law.
44	Cashew and soursop	Viçosa (MG), three brands were studies	SST below the minimum requirement in 33.3% of cashew pulps and 66.66% of soursop pulps.
45	Passion fruit	Bauru (SP), 25 samples from 7 different brands were studies	44%, 12%, and 8% of all samples do not meet the minimum requirements for STT, TTA and pH, respectively.
46	Pineapple, Acerola, soursop and mango	Interior, Ceará, samples from two small companies	TTA for soursop pulp, and TSS for acerola, soursop, and mango pulps.
47	Acerola and hog plum	Maceió, (AL), samples from one brand	None in terms of legislation on TTA, pH and vitamin C content.

TTA – Total titratable acidity in g citric acid (g/100 g), TSS – Total soluble solids (°Brix), TS – Total solids (g/100 g).

Diluting fruit pulps to reduce the total solid content (°Brix) to minimum levels required by the Brazilian legislation is a fault, since the law states that "fruit pulp is an unfermented, not concentrated and undiluted product obtained from pulpy fruits by a technical process and with a minimum total solid content from the fruits edible portion" [12].

The discrepancies of acidity and vitamin C content among the published data are mainly ascribed to the low quality of the fruits used to produce pulps, thus indicating fruit deterioration. Fruits improper to be eaten fresh due to complete decaying, mechanical injuries and deformations or breakage during transport are often used in pulp production.

It is worth pointing out that every activity, from postharvest to fruit processing, affects the phytochemicals and antioxidant properties of fresh fruits, the latter related to bioactive compounds beneficial to human health, such as vitamins C and E, carotenoids and polyphenols [32]. In this context, the determination of vitamin C content in fruits is very important because vitamin C degradation favors the appearance of non-enzymatic browning and bitter taste in fruit pulps [33]. Furthermore, vitamin C is an important food quality indicator due to its thermolabile nature. The presence of vitamin C in foods may lead to believe that other food nutrients are also preserved [33,34]. The processing method, storage condition, packaging, exposure to oxygen, light, and metallic catalysts, initial vitamin C content, and microbial load are among the principal factors that lead to vitamin C degradation [35].

Considering fruit pulp processing solely as a physical extraction method, the main aspects that must be controlled for pulp quality assurance are raw material quality, fruit washing/sanitization efficiency, processing time (prevent aeration or unnecessary lighting), and effective freezing procedures (observing the entire cold chain, processing, transport and sale to consumer). Campelo et al. [48] observed that the vitamin C content of acerola pulp produced in laboratory under controlled conditions decreased by 40% after 12-month storage. The remaining vitamin C content was still greater than the recommended daily intake (RDI), 90 mg/day. The lost vitamin C percentage decreased when acerola pulp was pasteurized before storing. Yamashita et al. [49] found that the vitamin C content of pasteurized acerola pulp reduced by 10 to 15% for storage times between 10 - 120 days, regardless of the freezing temperature (-12 and -18°C). On the other hand, fresh acerola fruits lost between 20 and 40% of vitamin C depending on the freezing temperature, with best vitamin C maintenance occurring at -18°C. Heat treatments involving temperatures above 60°C are able to inactivate enzymes. Therefore, vitamin C oxidation occurs throughout the exhaustion and pasteurization steps, but the remaining content becomes more stable after pasteurization due to enzyme inactivation [50].

In relation to acidity and pH analyses, Chitarra & Chitarra [51] reported that the ability to regulate some fruit derivatives can lead to broad variations in acidity without affecting pH, even though small pH variations interfere on the organoleptic characteristics of fruit pulps. pH is an important parameter because it influences directly organoleptic characteristics, microbial growth and selection of materials for the processing environment (corrosion) [39].

Organic acids, which are secondary products from fruit breathing metabolism, play a direct role on the development of characteristic flavor and aroma in fruits [42]. Titratable acidity and pH measurements provide an estimative of the deterioration level of certain types of foods, which is confirmed by the development of uncommon acidity or alkalinity [31]. High acidity values are related to low quality raw materials and excessive addition of acidulants, whereas low acidity values are likely due to dilution of fruit pulp to obtain minimum soluble solid contents (°Brix).

A parameter that is increasingly used to characterize fruit pulps is *Ratio* [37,39,45,52]. *Ratio* evaluates correctly the pulp taste, being more representative than individual measurements of sugars and acidity [53]. It consists of a relationship between total soluble solids content (°Brix) and acidity (g/100 g) (Equation 1).

$$Ratio = \frac{TSS}{TTA} \quad (1)$$

Another fruit pulp parameter easily determined is density (ρ). Equation 2 provides a relationship between density and total soluble solid content (10 - 18°Brix) at 30°C with correlation factor (R^2) of 0.91. This equation was based on analyses of acerola, cashew, soursop, mandarin and passion fruit [54].

$$\rho = 4.4181(TSS) + 997.61\ (Kg\ m^{-3})$$
$$Error = 1.7\% \quad (2)$$

Problems on microbiological standards of fruit pulps

The microbiological parameters listed in Table 4 allow concluding that the yeasts and molds counts were the most worrying index within the pulp production chain. Filamentous fungi and yeasts are the main cause of microbiological deterioration of fruit-derived products, mainly due to their growth capacity at low pH and anaerobiosis (yeast) [37].

Low counts of yeast and mold are considered to be normal (not significant) in fresh and frozen foods. On the contrary, high counts signify microbial spoilage, which may lead to product refusal, and represent a risk to public health because some mold species produce mycotoxins [27,55].

High counts of mold and yeast, with or without presence of bacterial coliforms strengthen the idea of inappropriate processing and/or post-processing contamination. This is possibly explained by the raw material quality, improper handling and dirty equipment or unsatisfactory sanitization procedures [10,27,56-58].

The mammal intestinal tract contains a myriad of microorganisms, representing a major source of foodborne pathogens. In absence or poor hygiene conditions, these enteric microorganisms contaminate manipulators and, consequently, the foods prepared by them [61]. Enteric bacteria commonly associated with food poisoning are *Salmonella sp.*, *Shigella sp.* and *Escherichia coli*, which belong to the coliforms group (total coliforms). This bacterial group is one of the best hygiene indicators in food processing. The fecal coliforms subgroup (commonly known as *E. coli)* is exclusive to mammal intestinal tract and relates specifically to total coliforms which have the ability to ferment lactose with gas production when they are incubated at 44 - 45°C [28]. *Salmonella* and *Shigella*, on the other hand, do not ferment lactose.

Spoilage bacteria, usually associated with genus *Acetobacter*, *Alicyclobacillus, Bacillus, Clostridium, Gluconobacter, Lactobacillus, Leuconostoc, Saccharobacter*, *Zymomonas* and *Zymobacter*, are native to fruit cultivation areas, where potentially pathogenic bacteria are nonexistent [37].

Studies listed in Table 4 reveal that lack of hygiene is related to the fecal coliforms group, although these cases were identified only in a small number of samples. These results lead to infer that the major microbiological problems are associated with the amount of yeasts and molds caused by the poor quality raw materials, inefficient fruit washing/sanitization steps and improper preservation of fruit pulps.

The two laws on microbiological standards for fruit pulp industry differ with respect to the microbiological parameters. While ANVISA focuses on pathogenic microorganisms, such as coliforms and *Salmonella*, MAPA focuses on hygiene aspects of the fruit pulp processing stages, mainly the fecal coliforms and molds and yeasts counts (common microorganism that grow very rapidly if the fruit pulp is not handled or stored properly).

Table 4 - Summary of published studies on microbiological analyses of tropical fruit pulps.

Reference	Fruit	Place/Additional information	Main reported irregularities
37	Mango	Zona da Mata (MG), samples from one brand	All pulps are in conformity with standards established by law.
60	Pineapple, acerola, hog plum, cashew, guava, soursop, papaya, mango, melon, passion fruit, siriguela, umbu	Russas (CE), 24 samples provided by a local medium-sized company	Conformity with respect to coliforms counts. 50% of samples presented counts of yeasts and molds above the permitted values. Lack of sanitary control and hygienic conditions during processing, cleaning, selection of raw materials and storage conditions. Absence of GMPs.
19	Pineapple, plum acerola, hog plum, guava, soursop, mango, mangaba, passion fruit, cherry and mandarin	Alagoas, samples from one brand but from three different sets	The most irregular samples were pineapple, plum, cashew, guava and passion fruit pulps constituting 30% of the pulps unfit for human consumption due to excessive count of yeasts and molds.
27	Açaí, acerola, bacuri, cashew, cupuaçu, passion fruit, tamarind and murici	Palmas (TO), samples from two growers in a local market	The pulps were in conformity with standards established by law with respect to total and fecal coliforms, but 29.6% of the samples were above the permitted yeasts and molds count values.
31	Pineapple, acerola, hog plum, cashew, guava and grape	Campina Grande (PB) 19 samples from 3 different brands	About 31.6% of the samples, pineapple, hog plum, guava and cashew, were not in conformity with the legal required standards. Contamination by yeasts and molds, salmonella and coliforms. Lack of sanitary control and hygienic conditions during processing, cleaning, and selection of raw materials. Absence of GMPs.
55	Acerola, cashew, guava, mango, passion fruit and strawberry	Datas (MG)	Pulps are in conformity with standards established by law in relation to total coliforms and Salmonella. For yeast and mold, only 25% of the pulps presented irregularities, which indicates inappropriate selection and/or processing of fruits and absence of GMPs.
56	Acerola, cupuaçu, guava and passion fruit	Boa Vista (RR), 5 different brands	There was irregularity in terms of molds and yeasts counts in 80% of acerola pulps, 64% of cupuaçu pulps, 92% of guava pulps and 76% of passion fruit pulps.
58	Açaí	Pouso Alegre (MG), 36 samples from 12 different stores	The microbiological quality was unsatisfactory. Sanitary measures are needed to reduce contamination level, such as efficient cleaning and sanitizing of equipment and utensils, adequate raw material and good storage conditions.
59	Several fruits	Freitas (BA), samples from 5 different stores	All pulps were contaminated by molds, yeasts and coliforms, but were within the legal standards, thus ensuring their hygienic quality.

GMPs, SOPs AND HACCP IN THE FRUIT PULP INDUSTRY

This topic addresses the relationships between quality aspects and food industry legislation. Among the tools available to create these relations are good manufacturing practices (GMPs), standard operating procedures (SOPs), microbiological risk assessment (MRA), quality management (ISO series), total quality management (TQM) and hazard analysis critical control points (HACCP) [1,62]. The Brazilian legislation obliges GMPs for any producer or food handler. GMPs are considered in 77% of the national or international certification processes, of which 50% use only GMPs to certify food products. Hence, GMP compliance is considered to be a minimum procedure for obtaining safe food products [63].

The most representative GMPs and SOPs texts, as well as water portability for food handling processes are described in the documents listed below:

- Ordinance No. 326 of July 30, 1997, of the Brazilian Ministry of Health, which declare a technical regulation on hygiene and sanitary conditions and good manufacturing practices for food companies;
- Ordinance No. 368 of September 4th, 1997, of the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA), which establishes technical regulations on hygiene and sanitary conditions and good manufacturing practices for food companies;
- RDC Resolution No. 275 October 21, 2002, of the Brazilian Health Surveillance Agency (ANVISA), which provides a technical regulation on standard operating procedures and a verification service for good manufacturing practices in food companies;
- Ordinance No. 2914 of September 12, 2011, which regulates procedures to monitor quality of water for human consumption.

The GMP manual has to include all parameters and control operations used within the food industry, and their respective periodicity monitored by a technician. The manual must declare general personal hygiene and training aspects, facility project, as well as production flowchart, and pest and quality control programs. The control periodicity must be established in the eight SOPs generally required for a food processing industry:

1. Hygiene of premises, machines and tools, which define the entire cleaning management process, its maintenance, sanitizer concentration, time and periodicity.
2. Water portability, which emphasizes water standards required in all process and its portability, with periodic analyses.
3. Hygiene and health of food handlers. The conduct and physical state of food handlers are an essential aspect of food quality. This SOP emphasizes the Program for Medical Control of Occupational Health (PMCOH), training periodicity and employees conduct required in a processing area.
4. Waste management, referring to management of residues generated in the industry.
5. Preventive maintenance and calibration of equipments, which indicates the need for maintenance of equipment and premises in the processing area.
6. Integrated management of vector and urban pests, which defines potential pests and vectors, as well as the methods and their periodicity to avoid presence of pests in the processing area.
7. Selection and reception of raw materials, packaging and ingredients. Important item that safeguards the traceability of all inputs used in fruit pulp production. This is one the most important fundaments of food product safety.
8. Food gathering program. Food companies are also responsible for withdrawal products from market if the food expiration date is exceeded. This SOP establishes the final management of unsold products.

Hazard Analysis Critical Control Points (HACCP) provides guidance on how to identify biological, chemical and physical hazards in a particular food processing line and how to control them at the Critical Control Points (CCP) throughout production [1,64]. Some HACCP implementation attempts in vegetal food area, such as olive oil and minimally processed vegetables, have already been published, and revealed that the use of HACCP as a control system tool is a natural trend [65,66]. Nevertheless, the current Brazilian legislation requires HACCP only for animal food

companies, such as meat, milk, honey and their derivative products. The fruit processing industry is still exempt from HACCP, but this requirement will tend to be gradually imposed over the years.
The four actions (5S program, GMPs, SOPs and HACCP) constitute the pyramid quality basis. According to this pyramid, food product standardization recognized nationally and internationally (ISO, for example) is only accomplished when all four actions are formed and well adapted to real industrial conditions [10].
Investigations aim to discover existence of hazards to health and integrity of consumers. It is performed by inspecting raw materials and all relevant production chain stages, including product consumption by consumers. These investigations are focused on:

- Microbiologically susceptible foods that favor microbial growth and toxin production;
- Pathogenic microorganisms or toxic substances;
- Inadequate heat treatment, that is, inadequate time-temperature combinations;
- Inadequate procedures after heat treatment;
- Environmental conditions that allow the transfer of pathogenic microorganisms or toxic substance to foods through air, water or other vectors [1,10,64].

Microbiological analyses should be carried out in stages of sanitization, peeling, pulping, heat treatment or preservative addition and freezing, in order to minimize significant microbial proliferation or existence of physical or chemical hazards.
In general, safety management may be assumed as the sum of risks management that is usually administered by the government at a macro level. The government supervises and establishes IQSs for food products, while the food production sector executes the risk management, not only in terms of application, but also maintenance through quality tools such as GMPs, SOPs, HACCP, ISO etc. This ensures that good quality food products will be available to consumers [63].

CONCLUDING REMARKS

Quality of fruit pulps involves various control aspects that must be respected in order to offer high nutritional, microbiological and sensory quality product to consumers. The increasing number of fruit pulp producers, generally represented by small groups of producers without skilled labor, constant hygiene facilities inspection, and standard pulp conservation procedures, jeopardizes the expansion of the entire Brazilian fruit pulp economy, mainly in relation to the use of fruit pulps for manufacturing other products (juices and ice creams) and exportation. Correct washing and sanitization of good quality fresh fruits may be responsible for the absence of microbial load or pathogenic microorganisms in fruit pulps. Diluting fruit pulps to increase pulp yield and adjust the minimum total soluble solid content must be abolished because it is not permitted by law, even if this procedure is justified by the decrease of pulp viscosity. Adoption of HACCP could help strengthen the microbiological control within all fruit pulp processing lines. Effective inspections on small and micro-sized companies should be adopted by governmental agencies. Data listed in this article reveal that a public health crisis in underway once fruit pulps are frequently distributed from the industries directly to markets.

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