Chapter 16
Technology of Fermented Mango Juice Production

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Abbreviations

%	percentage
° C	Celsius degree
g	Gram
g/l	gram per liter
Kcal	Kilocalorie
me/Kg	milliequivalent per kilogram
me/L	milliequivalent per milliliter
mg	Milligram
mcg	Microgram
IU	International Units

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16.1 Introduction

The fermentation seems to be appeared in Iarq with cheese fabrication in the period 8000–6000 BC. She was largely used as means to preservation and transformation foods. Later, in the period 4000–2000 BC, Egyptians discovered how to use yeasts to make leavened bread and wine (Ross et al. 2020). Today, a large variety of foods obtained through fermentation are consumed in the world and have the good reputation regarding their organoleptic and sensory properties, including cheese, yoghurt, kefir, beer, kombucha, pozol, sourdough, kimchi, olives, sauerkraut, pickles, tempe, gari, fufu or sausages (Tamang et al. 2016).

Fruit consumption has a recognized health benefit which may be associated with the antioxidant and nutritional potential of fruits. It is the mango (*Mangifera Indica L*) case which, with the chemical composition of the pulp, her consumption is highly recommended in cases of skin and retinal diseases, arteriosclerosis, high blood pressure and diabetes (Pamploma 2007). Mango is more nutritious than most fruits in temperate countries (FAO 1993). The recommended daily intake of 5 servings of fruit however seems difficult to achieve. Some of the difficulties commonly mentioned by consumers in achieving the recommended intake of the fruits are their high prices, seasonality, fragility, and low shelf-life. Drinking of fruit juices, is an attractive alternate means of intake of fruits to obtain the desired nutritional and health benefits. Indeed, with fruit consumption, a growing market is developing around fruit juices with new tastes and high nutritional values.

However, after the manufacturing, the fruits juices are confronted with a problem of stability and this until it reaches the table of the consumer, the fruity beverage under goes various types of changes which directly influence the nutritional and organoleptic qualities. In general, the technology of fruit juice preservation is thermal processes that require energy and action of the temperature/time pair (Baron 2002; Aymerich et al. 2008). These thermal methods have drawbacks such as such their energivorous character and the destruction of aromatic compounds due to their volatile nature thereby greatly reducing the nutritional and organoleptic quality of the juices. In addition, these thermal methods require considerable investment in special equipment (Branyik et al. 2010). Thus, the biological method through fermentation with the use of non-*Saccharomyces* yeasts remains an ecologically and economically viable solution. The most wide spread biotechnological approaches rely on the limited or almost zero formation of ethanol by the yeast during fermentation. Limited fermentation is generally carried out in equipment which requires no additional investment. Also, the fermentation brings about the reduction of sugar content and the intensification of flavor (Romano et al. 2003). In addition, the pectinolytic activity (polygalacturonase) of microorganisms involved the fermentation of fruit juice contributes to clarification thereby avoiding a supplementary operation in the production process (Thakur et al. 2010). Use non-*Saccharomyces* yeasts strains appear as the suitable tool to carry out the fruit juices fermentation. In according to

Renouf (2006), "Non-*Saccharomyces*" yeasts include all yeasts with the exception of *Saccharomyces* species and constitute a large and very diverse group. These non-*Saccharomyces* yeasts have high potential impact on biotechnology, namely a significant aromatic contribution and an inhibition of undesirable microorganisms (Bonilla-Sallnas et al. 1995; Renouf 2006). In this review the fermented mango juice production process will be explained.

16.2 Botanical Origin of Mango

The mango tree, *Mangifera indica*, is come from to a region on the Indo-Burmese border. The mango tree can grow up to 30 meters tall and is adapted to a wide tropical climatic range with highly variable annual rainfall and can grow on a wide variety of soils. Optimal temperatures for tree development and fruit growth are ranged between 24 and 30 °C (Fruitrop 2009).

The shape of the fruit is the basis of the paisley pattern. The mango is a fleshy fruit, weighing from 300 g to 2 kg. It is a drupe, its flesh adheres to a large, flat and slippery pit. It can be round, oval or kidney-shaped and has a rind that can be yellow, green or red in colour, which must be removed as it contains irritants and is therefore inedible. The flesh is dark yellow, smooth, fatty and sweet with a false taste of peach and flower. Depending on the variety or when the fruit is overripe, the flesh sometimes becomes stringy. (Fréhaut 2001).

It is also characterized by the presence of lenticels on the entire surface of the skin. The pulp adheres to a large, more or less flattened core and is essentially made up of parenchymal cells (Fig. 16.1). By selection, the mesocarp is nowadays not very fibrous.

Currently, mango is present throughout the intertropical zone and to a lesser extent in the Mediterranean region (Egypt, Spain, Israel, etc.) (Braz 2004). It is found throughout South-East Asia, West Africa, Hawaii, and in all lowlands of Central and South America.

Fig. 16.1 Diagram of mango fruit (Fruitrop 2009; website: http://waynesword.palomar.edu/ecoph9.htm)

16.3 Mango Varieties

More than thousands varieties of mango has been recensed in the world. In terms of the characteristics of the fruit, the differences between these varieties are ranged taste, colour of the flesh and skin, size, format, amount of fiber, resistance to transport and storage, resistance to disease and insects, etc. In many countries, mango is plays an important in the diet of people. Originally, there were two main families of mango, with very different characteristics, which come from two diversification basins, the Indian sub-region and tropical Asia. Currently, several commercial varieties were selected in Florida in the early twentieth century from multiple hybrids using progenitors from these two families. The fruit exported is generally from grafted plants. The main mango varieties are: Tommy Atkins, Kent, Keitt, Osteen, Haden, Valencia Pride, Kumquat, Lime, they are practically present in all regions of the world (Rey et al. 2004).

In Africa, particularly in West and Central Africa, the *Nunkourouni mango* variety characterized through fibers and polyembryos. Her name depended of region where is cultived, example of Sierra Leone to Senegal, she is called German mango, in Adamaoua, Cameroon it N'gaoundéré mango, In Côte d'Ivoire her name is *assabonou.*

16.4 Biochemical Composition and Nutritional Value

The mango is very rich in water more than 80% and polysaccharides but poor in protein and lipids and caloric value is to 56 Kcal for 100 g of fruit. The content of biochemical composition and value nutritional is indicated in Table 16.1. However, these values varying with varieties. In according Lakshminarayana et al., (1970), the starch rate contained in skin and pulp increases continuously between the phases of fruit formation and harvest maturity. On the hand over, Silva et al. (2008) reported that the starch content decreased during ripening under action of some enzyme as β-amylase while the soluble sugars content increases. For example, for Badami variety Shashirekha and Patwardhan (1976) demonstrated an increase in glucose (420–4200 mg/100 g), fructose (560–4300 mg/100 g) and sucrose (16–4400 mg/100 g) during ripening. Moreover, mango fruit is appreciated for its richness in antioxidants (vitamin C, carotenoids and polyphenols) and minerals (calcium and potassium) (Table 16.1).

Table 16.1 Mango pulp composition (USDA, Nutrient Database for Stanadrd Référence 2001)

Constituent	Amount in 100 g fresh pulp
Water	81.7 g
Energy	65 kcal
Protein	0.51 g
Fats	0.27 g
Carbohydrates	17 g
Total dietary fiber	1.8 g
Ash	0.5 g
Minerals	
Calcium	10 mg
Iron	0.13 mg
Magnesium	9 mg
Phosphorus	11 mg
Potassium	136 mg
Sodium	2 mg
Zinc	0.04 mg
Copper	0.11 mg
Manganese	0.027 mg
Selenium	0.6 mcg
Vitamins	
Vitamin C (total ascorbic acid)	27.2 mg
Thiamine	0.056 mg
Riboflavin	0.57 mg
Niacin	0.584 mg
Pantothenic acid	0.16 mg
Vitamin B_6	0.160 mg
Total folate	14 mcg
Vitamin A	3894 IU
Vitamin A	389 mcg RE
Vitamin E	1120 mg ATE
Tocopherols alpha	112 mg
Lipids	
Total saturated fatty acids	0.066 g
Total monounsaturated fatty acids	0.0101 g
Total poly unsaturated fatty acids	0.031 g
Cholesterol	0.00 mg
Amino acids	
Tryptophan	0.008 g
Threonine	0.019 g
Isoleucine	0.018 g
Leucine	0.031 g
Lysine	0.041 g
Methionine	0.005 g

(continued)

Table 16.1 (continued)

Constituent	Amount in 100 g fresh pulp
Phenylalamine	0.017 g
Tyrosine	0.01 g
Valine	0.026 g
Arginine	0.019 g
Histidine	0.012 g
Alanine	0.031 g
Aspartic acid	0.042 g
Glutamic acid	0.06 g
Glycine	0.021 g
Proline	0.018 g
Serine	0.022 g

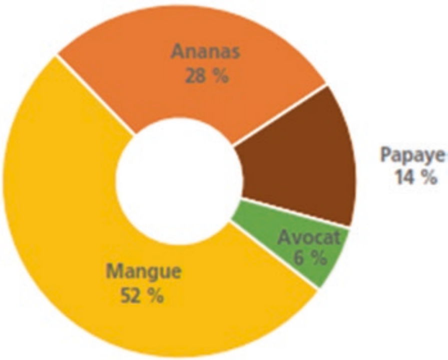


Fig. 16.2 Main Tropical Fruits: production volume by type in 2018

16.5 Mango Production

In according to statistics from the FAO's Intergovernmental Group on Tropical Fruits, world mango production increased by an average of 3.03% per year from 2008 to 2018, from 38 million tons to 52 million tons. In terms of production volumes, the mango has maintained its position as the dominant tropical fruit, due to its popularity in India, where an estimated production to 38% of production worldwide. The world's mango production accounted for more than half of the total world production of the main tropical fruits in 2018 (Fig. 16.2) (FAO 2020). The African continent is the second largest producer of mangoes after Asia. Its production increased by 1.07% from 3.9 million tons in 2008 to 8.2 million tons in 2018. Production in Central American and Caribbean countries has increased slightly, from almost 2.8 million tons in 2008 to 3.3 million tons in 2018. It is concentrated in Mexico, followed by Cuba and Haiti.

16.6 Mango Varieties Used for Juice Production

Several mango varieties exists but all varieties are not used to produce the juice. To be used for juice produce mango must be to satisfy some criteria. Indeed, in Burkina Faso, Traore et al., (2017) reported that the varieties *Amélie, Brooks, Kent, Lippens* and *Springfield* were most transformed. The criteria of these choices were the availability, use easily and growing demand. Also, the pulp must be very homogeneous, of creamy consistency, with a colour ranging from greenish white to orange-yellow. In Congo, an improved variety mango called "Boko" had been used to produce the juice. In fact, the mango "Boko" presented physical and organoleptic characteristics very special particularly taste and aromatic qualities compared to other mangoes (Diakabana et al. 2013). On the hand over, others varieties as *Alphonse, Badami, Lamy N°2, Peter Pasand, Taymour* have been reported in mango juice production in Senegal (Vallet 1965). The Fig. 16.3 illustrated some mango varieties used in mango juice production.

A: Amelie variety; B: Lippens variety; C: Kent variety; D: Brooks variety; E:Springfield variety (Traore et al. 2017).

16.7 Mango Transformation Situation in Developing Countries

World production of mango pulp is estimated at 700000 tons per year, half of which is produced in India. The country consumes around 150,000 tons per year and exports some 200,000 tons. Processing should become a key step in adding value to mango in developing countries, where crop losses regularly exceed one-third of

Fig. 16.3 Some mango varieties used in transformations

production and the subsequent loss of earnings are significant. To date, mango processing remains a marginal activity, using less than 2–5% of the harvest, and includes the manufacture of dried mango, juice, nectar, mango vinegar and jam. Processing takes place in artisanal units (women's groups), semi-industrial units, and very few industrial units. Two main factors that determine this situation are the short harvest seasons, with peaks from May/June to July/August depending on the country and variety, and the lack of possibilities to supply processing units with other fruits outside the mango season. Other factors include the lack of an organized circuit for supplying processing units with quality mangoes at acceptable and non-fluctuating prices; the lack of knowledge of the demand for processed mangoes on national, regional and international markets, as well as the absence of conservation infrastructures and techniques, adapted processing technologies and know-how of operators (ECOWAS 2011).

16.8 Steps of Mango Juice Production Fermented

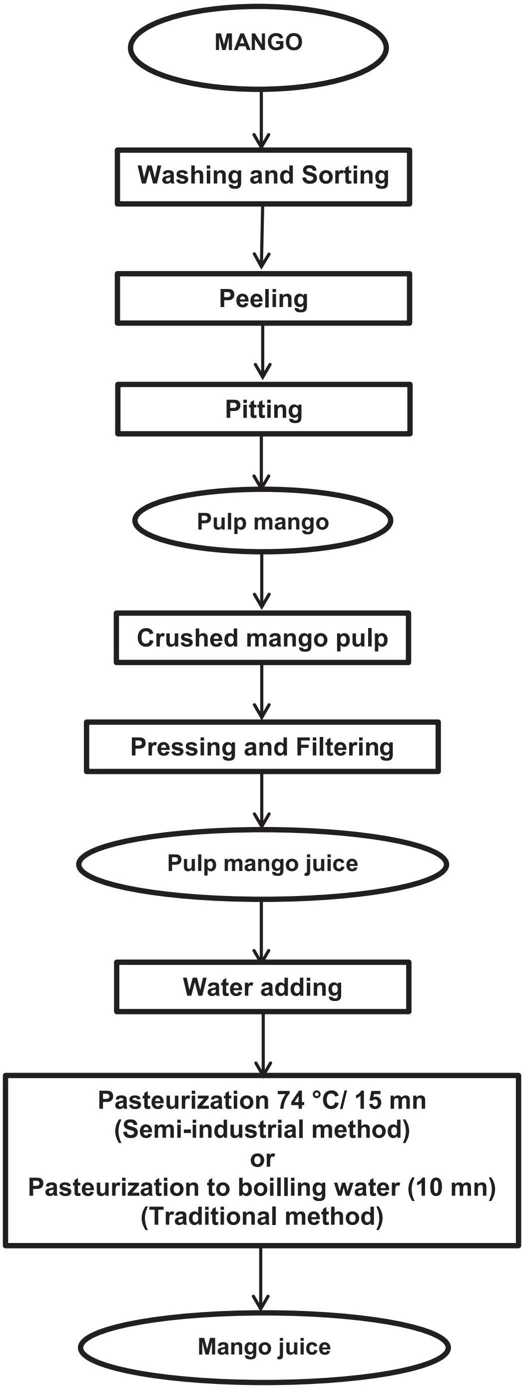
16.8.1 Mango Juice Production

The mango juice production fermented consists two steps: firstly the mango juice production and the secondly the fermentation. The mango juice is the unfermented filtrate from the previously crushed mango pulp. The mango juice retains the physicochemical, nutritional and organoleptic characteristics (flavors) of the mango variety from which it is extracted. Consumed fresh, the mango juice, rich in carotene, vitamins C, B1, B2 and minerals, is an excellent beverage for people of all ages (FIRCA 2014). The steps of mango juice production are presented in Fig. 16.4. Once produced, the raw juice, which comes from the crushing of the pulp, is in reality a homogenized pulp, because the pieces are so fine in texture that they give up little more than a few fibers. The result is a homogenized cream that is pleasant to taste but impossible to drink. Attempts at partial clarification, by filtration or enzymatic action, have failed. Rapid centrifugation gives only an incomplete separation of 10 to 20% of the supernatant liquid in 15 or 30 minutes; heating to boiling does not precipitate anything and filtration after heating is no faster; similarly, freezing has not destroyed the structure of the suspension (Vallet 1965).

The addition of water gives a nice looking drink, as the decantation of the pulp is very slow. In addition, to obtain a pleasant drink, it is necessary to sweeten and acidify. Indeed, the dry extract of the pulp is around 15%, and its acidity is low (35 me/kg), so that the addition of 3 volumes of water would give a tasteless drink, it is necessary to bring the sugar content between 100 and 150 g/I and the acidity around 100 me/l in the finished drink. The simplest way is to prepare the solution in advance by adding sucrose and citric acid in suitable proportions (Vallet 1965).

On the hand over, pressing alone does not allow for maximum juice extraction, which represents a financial loss for the industry. In addition, some fruits such as

Fig. 16.4 Mango juice production diagram



mango and plum are poorly suited to pressing (Chang et al. 1995; Chauhan et al. 2001; Will and Dietrich 2006). Further research led to the first application of pectolytic enzymes in this technology for apple juice clarification in 1930 (Mehlitz 1930). For juice extraction, it is necessary to act upstream of pressing by physical and/or enzymatic actions in order to increase the yield by facilitating extraction through increased destructuring of the fruit, and/or downstream to remove cloudiness and obtain clarified juices.

16.8.2 Mango Juice Fermentation

The mango juice fermentation can to carry out of two methods, the spontaneous fermentation and the controlled fermentation. La spontaneous fermentation is carried out through the microbial presents in environment and material raw during 5 to 7 days. The problem of this fermentation it the possible present of undesirables microorganisms. Also the high content of sugar in mango juice can give the alcoholic fermentation. For this fermentation, the mango juice is not pasteurized to preamble.

Few studies were focused in mango juice fermentation, however, Coulibaly et al. (2019) were studied the mango juice controlled fermentation by non-*Saccharomyces* yeasts species using. Indeed the non-*Saccharomyces* yeasts are recognized for their contribution to the aromatic quality than for the formation of alcohol during fermentation (Romano et al. 2003). Also, Coulibaly et al. (2019) reported that mango juice fermented with *Hanseniaspora. jacobsenii* had the lowest ethanol content 1.2 ± 0.08% (v/v). In according Arendt et al. (2018), beers produced through non-Saccharomyces strains as *Hanseniaspora valbyensis, Hanseniaspora vineae, Torulaspora delbrueckii, Zygosaccharomyces bailii and Zygosaccharomyces kombuchaensis* species isolated from Kombucha a non-alcoholic medium, have low the ethanol content between 0.34 and 0.5% (v/v). Also, *Pichia kluyveri* strains were used to produce an alcohol-free beer (0.1% v/v alcohol) and a low alcohol beer (0.7% v/v alcohol) (Saerens and Swiegers 2017). However, some studies were focused in alcoholic beverage from mango juice for production of wine and beers (Carle 1924; Vallet 1965; Diakabana et al. 2013).

Also, INRA (Institut National de Recherches Agronomiques) has developed a processing to produce fermented fruit juice which remains applicable to mango. These drinks are obtained by fermenting aqueous extracts of fruits (macerations) or other aromatic plant resources, in the presence of a yeast strain added to control fermentation. This type of drink is traditionally made within the family from macerations in water of fruit remains: pineapple, cytherea, etc. This practice is common in Martinique and makes it possible to make the most of the fruit harvested from domestic gardens and orchards. It produces aromatic, sparkling and refreshing drinks that can be kept for a few days in the refrigerator. The process developed by INRA in 1990 makes it possible to produce in a controlled manner a product of constant quality that can be kept for a long time at room temperature, like the products sold in supermarkets. The fruit pulp is mixed with water. Enzymatic treatments with pectinases can be performed to better extract the compounds from the pulp. The aqueous extract obtained is clarified by sieving and decanting. Its sugar content is adjusted by adding syrup, which provides sufficient substrate for the alcoholic fermentation yeasts, depending on the desired alcoholic strength.

The sugar extract is inoculated with low-alcohol yeast, such as *Kloeckera apiculata*. Alternatively, the yeasts present on the fruit can be left to do their job. Fermentation will be a little longer and variable. Fermentation is carried out using the closed tank technique. At home, bottles are used and sealed with caps or corks.

After fermentation, the product is pressure-filtered or decanted and then packaged in clean, hermetically sealed bottles.

*16.8.3 Non-*Saccharomyces *Yeasts*

16.8.3.1 Non-*Saccharomyces* Yeasts Strains Used in Fermentation

In according Quoc (2010) Non-*Saccharomyces* yeasts represents a large group of micro-organisms presents in several areas of fermentation, extremely diverse in terms of taxonomy and technological properties. Generally, among non-*Saccharomyces* yeasts genera encountered in fermentation there are: *Hanseniaspora, Candida, Issatchenkia, Pichia, Kluyveromyces, Metschnikowia, Zygosaccharomyces, Zygoascus, Torulaspora, Debaryomyces and Brettanomyces.*

16.8.3.2 The Interest of Non-*Saccharomyces* Species in Fruit Juice Fermentation

Non-*Saccharomyces* species have long been considered harmful for alcoholic fermentation. Recent studies show that some of them have real potential. Non-Saccharomyces can, among other things, release fermentative aromas, contribute to organoleptic complexity, develop enzymatic activities of interest (*Pichia kluyverii* and *Metschnikowia pulcherima*), deacidify (*Hanseniaspora occidentalis*), promote the formation of varietal aromas (*Torulaspora delbrueckii, Metschnikowia pulcherima* and *Kluyveromyces thermotolerans*), produce low volatile acidity (*Torulaspora delbrueckii*) (Lamon 2013). However the characteristics of non-*Saccharomyces* yeasts strains could depend the ecological niche where there have been isolated.

16.8.4 Microbiological Decontamination Processes

In general, because of their low pH, fruit juices present little microbiological risk. A pH below 4.5 is lethal for pathogens such as *Listeria monocytogenes* or *Clostridium botulinum* (Parish and Higgins 1989). However, outbreaks of diarrhea and haemolytic uraemia syndromes in 1991 in Massachusetts (USA) were associated with the consumption of unpasteurized apple juice containing the pathogenic strain *E. Coli* O157:H7 (Besser et al. 1993). In Libya, 146 unpasteurized juices were found to contain viable microorganisms ranging from 1.7.105 (almond juice) to 5.1.103 (lemon juice) (Ghenghesh et al. 2005). Of these microorganisms found in juices, many are pathogenic to humans, such as the *E. Coli* 0157. At the end of the production chain, fruit juices must be free of microorganisms in quantities that could present a health hazard until the use by date. Controlling micro-organisms is therefore essential to ensure the sanitary and microbiological quality of juices, to ensure their stability and to extend their shelf life. There are several decontamination treatments based on the thermoresistance, baroresistance, etc. of microorganisms. The process classically used for pasteurization is as follows: the full closed bottles are sprayed with increasingly hot water until temperatures of around 90 °C are reached, which heats the product from 82 °C to 85 °C. This "pasteurization" technique, developed by Pasteur, requires lengthy heating and cooling procedures that can cause the fruit juice to cook and degrade its flavors. Pasteurization has negative effects: at 80 °C, non-enzymatic browning can occur, loss of heat-labile nutrients and formation of undesirable products such as 5-hydroxymethylfurfural (5HMF) (Baron 2002). However, many studies show that these new compounds formed during the Maillard reaction have strong antioxidant activity (Kim et al. 2003; Del Caro et al. 2004). The first alternative to conventional pasteurization is rapid heating: the glass containers are filled with juice heated to 95/97 °C. The juice/bottle assembly after closure with a temperature of 82 °C to 85 °C is self-pasteurizing. This combination is then rapidly cooled. This technique, known as "flash pasteurization", reduces the intensity of the heat treatment by half. Good asepsis control allows the thermal scale to be reduced even further (Baron 2002; Aymerich et al. 2008). Flash pasteurization can be followed by aseptic cold filling. The packages are sterilized in an aseptic environment before the filling operation. The fruit juices are sterilized by flash pasteurization (at 95/97 °C) and then cooled to room temperature within seconds before being cold-filled into the aseptic package. However, strict hygiene rules must be followed to avoid post-pasteurization recontamination. Many fruit juice distributors (Andros, Pampryl) have mastered this cold filling process, as their packaging does not withstand the pasteurization temperature.

16.9 Some Definitions

- **Fruit juice**

In according to Codex Stan 247-(2005), fruit juice is a fermentable but unfermented liquid that is obtained from fruit by mechanical processes that retain the essential physical, chemical, organoleptic and nutritional characteristics of the fruit from which it is obtained. A single juice is obtained from a single type of fruit.

- **Cocktail**

A cocktail is a mixture obtained by mixing two or more juices and puree from different types of fruit (Liegeois 2003).

- **Fruits beverages**

The name "fruit beverage"or "fruit juice beverage" or "fruit pulp beverage" is reserved for beverages prepared from drinking water and fruit juice, fruit concentrate or a mixture of both; in a proportion equal to or greater than 10% juice. (International regulations).

16.10 Different Categories of Fruit Juice

The two main categories of fruit juice are pure fruit juice and fruit juice from concentrate.

- **Pure fruit juices**

Identified by the label 100% pure fruit juice: they are distinguished into "pure fresh fruit juice", free pasteurization, and "pure juice" pasteurized after extraction (or pressing). They contain no additives and no added sugar (Liegeois 2003).

- **Fruit juices from concentrate**

These are obtained from concentrated fruit juices from which the water is removed by dehydration at the place of production in order to reduce transport costs. The proportion of water extracted during the concentration process is then restored, this water having appropriate characteristics to guarantee the essential qualities of the juice. The flavor is also restored by means of the aromatic substances recovered during the concentration of the fruit juice, which is fruit juice of the same species (Bourgeois and Leveau 2003).

To these two categories should be added nectars, which are obtained by mixing, in a given ratio, fruit puree and syrup or sugar; as well as: sweetened fruit juice; fruit drink; carbonated juice; sweetened juice (concentrate); fermented juice, milky juice (Benama and Agougou 2003).

16.11 Others Products of Mango Transformations

Excepted the juices, mango is used to produce others several food products as syrup, dried pulp mango, nectar, jam (Litz 1997). Indeed Traoré et al. (2017) reported that use mango to produce dried mango, nectar and jam to Burkina Faso. Also, in Côte d'Ivoire many foods have been produced from mango: jam, syrup, nectar, mango jelly, mango pulp preserves, mango pulp in syrup, mango puree, mango pulp powder (FIRCA 2014).

16.12 Conclusion

Juice and nectar remains the mains products from mango transformation. The mango used for juice production must be answered to some criteria. Thus, the fermentation of mango juice remains a mean to guaranty organoleptic quality and microbiological stability. Also, non-*Saccharomyces* yeasts strains are more suitable for carried out this fermentation.

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