Chewing Gum: Production, Quality Parameters and Opportunities for Delivering Bioactive Compounds

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Abstract

Background

Chewing gum has an amazing statistics. The entire industry is worth $25 billion and annually 1.74 trillion sticks of **chewing gum** are produced. It would account for 290 billion hours' duration of staying in mouth if each piece of gum was chewed for 10 min every year. Concerning these statistics at least smoke cessation, oral health and new form of drug delivery system potentials of **chewing gum** are clear. Therefore, fundamentals of chewing gum should be realized in detail to take the advantage of this product.

Scope and approach

In this review, due to limited studies concerning **chewing gum** in food science and technology area, key points in production, quality parameters and **bioactive compounds** delivering properties of **chewing gum** were reviewed with aim to show promising study areas to researchers. Production of different types of gums, ingredients used, sensory and **texture** properties and potential future functions of **chewing gum**s were discussed with a special emphasis on the **bioactive compounds** carrier properties of **chewing gum**.

Key findings and conclusions

Encapsulation not only improved a sensation of **flavor** for a long period when applied in the **chewing gum** but also had a potential to give functionality to **chewing gum**. Only recently the idea of healthy **chewing gum**s and using **chewing gum** as an alternative form of drug delivery system have been developed. Therefore, food technologists should give attention to this promising subject of producing **chewing**

gums having long lasting **flavor**s, being biodegradable and forming a type of functional confection consumed with pleasure by everyone.

Keywords

Chewing gum; flavor; texture; bioactive compounds

1. Introduction

The consumption of confectionery products has grown tremendously in recent years, especially among children and teenagers (Carbonell-Barinchina, Garcia, Sanchez Soriano, Aracil, & Burlo, 2002) and chewing gum is a popular confectionery product worldwide (Wong, Yu, Curran, & Zhou, 2009; Yang, Yin, & Shao, 2011). It is consumed by a diverse set of consumers. Also accessibility is another advantage (Hearthy, Lau, & Roberts, 2014). Especially, people enjoy it as a confection and latterly as an aid in oral hygiene and an alternative to smoking (McGowan, Padua, & Lee, 2005).

Chewing gums have rubbery-like structure and depending on the type of final product they are composed of various ingredients such as sugar, polyols, gum base, aroma, acidulants, colors, sweeteners and different additives, (Valduga, Lazzari, Xardanega, & Luccio, 2012). It is a two-phase product and consists of water-soluble continuous phase and - discontinuous phase which is gum base. These phases are generally mixed in proportion of 1:3, respectively. Flavoring ingredient concentration of chewing gum is approximately 1% (Potineni & Peterson, 2008a). Chewing gum is generally produced from chicle, a natural latex raw material, or polyisobutylene (Baysal, Ozbek, & Akman, 2010).

Chewing gum plays an important role in the confectionery industry (Valduga et al., 2012). Moreover, chewing gums have been produced for treating disorder/disease conditions like inhibition of dental disorders, appetite arrangement delivery, smoking mimetics, carriers of functional ingredients and regulation of stress and mood changes (Deshpande & Jadad, 2008; Ribelles, Guinot, Mayne, & Bellet, 2010; Hearthy et al., 2014; Hetherington & Regan, 2011; Hearthy et al., 2014; Smith, Chaplalin, & Wadsworth, 2012).

According to Euromonitor International Gmbh, the sales value in chewing gum market is 25 billion dollars in the world in 2014 (Euromonitor, 2014). Annual chewing gum consumption rate in America was reported to be 160-180 sticks per person. Although these statistical data showed that chewing gum market is very huge, studies about chewing gum is scarce. Chewing gum will be expected to attract great attention from industry and scientific world in the near future for several reasons including its high consumption rate, importance of chewing gum market in the confectionery industry and potential health benefits by delivering bioactive compounds. Therefore, from production to quality parameters of the finished product, critical aspects of chewing gum was reviewed with special emphasis on its potential of delivering bioactive compounds. This study will provide insight into the optimization of formulation and manufacturing process to obtain the product with desired quality. The present work included classification of chewing gums, ingredients used in the formulation, production processes, quality parameters and opportunities in terms of delivering bioactive compounds.

2. Classification, Ingredients and Process

2.1. Classification

Chewing gums are mainly classified into 4 groups: (i) sugar chewing gum, (ii) sugar-free chewing gum, (iii) coated chewing gum and (iv) medicated chewing gum.

General composition of sugar and sugar-free chewing gums is summarized in Fig. 1. Sugar chewing gums contain almost 80 weight % sugar and glucose syrup mixed with gum base. The main difference between sugar chewing gum and sugar-free chewing gum depends on substitution of different sugar alcohols and high intensity sweeteners for sugar and glucose syrup. Concerning the coated chewing gum, coating is used to improve visual impact of the product and control of the water activity and shelf life. Sugar, sugar-free and coated chewing gum with different flavors, shapes and sizes are produced in the industry. Chewing gum having the property of blowing bubbles due to film forming characteristics is called a bubble gum. Concerning the other type of gums, center-filled gums has flavored liquid in the form of soft mass in its center. Depending on its shapes there are also ball gum, stick gum, ribbon gum, tab gum, tube gum, dragee gum and wrap gum in the market. Moreover, for various human needs, tailormade chewing gums can be made which is called functional gum. Vitamins and minerals can be added to gum giving practical function to it.

Medicated chewing gums include pharmaceutical or nutraceutical compounds which are released in a controlled manner during chewing and therefore they are accepted as drug delivery systems (Maggi, Conte, Nhamias, Grenier, & Vergnault, 2013). According to the European Pharmacopoeia and report prepared for pharmaceutical dosage forms in 1991 by the Committee for Medicinal Products for Human Use (CPMP), medicated chewing gums are described as “solid single dose preparations with a base consisting mainly of gum that are intended to be chewed but not to be swallowed, providing a slow steady release of the medicine contained" (Paradkar, Gajra, & Patel, 2015). Chewing gums are attractive and effective alternative drug delivery systems when these factors are considered;people of all age savorily chew gums, release of active substance can be controlled, buccal drug administration for the treatment of local oral diseases can be effective and it can make oral administration very convenient(Yang, Wang, & Zhang, 2004). They are suitable for therapeutic uses such as preventing oral cavity, treatment of motion sickness and otitis media, smoke cessation, pain reliever, antioxidant, oral antifungal, alertness, anti-nausea, anti-emetic, anti-septic, healing, etc. since they are chewed in the mouth for a long duration. Moreover since the bioactive compound or drug is absorbed by oral mucose, chewing gums can provide a faster onset of therapeutic effect and potentially reduce gastrointestinal and hepatic first-pass metabolism of susceptible drugs (Maggi et al., 2013). Investigations on the bioavailability and distribution of some active substances in tissue showed the advantages of chewing gums (Yang et al., 2004).

2.2. Ingredients

Chewing gum is generally fabricated by mixing of a required amount of water-insoluble gum base and different additives which are sweeteners, softeners, food colorings, preservatives (Yang et al., 2011). It consists of two phases; (i) gum phase (water-insoluble), and (ii) sugar or sugar alcohol phase (water-soluble). Regarding coated chewing gum, it is possible to specify the compound material as a third phase. Corn syrup and/or glucose are employed as humectants and they play an important role in coating of the sugar particles to stabilize their suspension and in maintaining flexibility of the product (Wong et al., 2009). Amount and size of the granulated sugar present in these phases are responsible for the texture of the end product, Moreover, various softeners, food colorings, preservatives, and flavorings are used in the formulation to produce the product with desired quality.

It has been reported that the composition of chewing gum (for example the chewing gum bases, the carbohydrate and solvent) could affect the retronasal aroma release (Soutmann, Van Lochem, & De Roos, 2003; Potineni & Peterson, 2008a,b; Itobe, Kumazawa, Inagaki, & Nishimura, 2012), and the composition of chewing gum is assumed to have some effects on the elution characteristics of odorants. Therefore, examining the impact of the composition of chewing gum on the aroma release will also be one of the future challenges (Itobe et al., 2012).

2.2.1 Gum base

A properly selected base provides the chewing gum with its mechanical masticatory properties (Tisdale & Wilkins, 2014). The main composition of chewing gum is base gum or base mass (20-30%) (Valduga et al., 2012). Gum base includes elastomer (10-30%), elastomer solvent (2-18%), polyvinyl acetate (15-45%), emulsifier (2-10%), low molecular weight polyethylene (0.5-15.0%), waxes (0.5-10.0%), plasticizer (20-35%) and fillers (0.0-5.0%). Although exact compositions of gum bases are generally a trade secret, they usually include elastomers and resins, along with fats, waxes, emulsifiers, fillers and antioxidants (Fritz, 2006).

Several synthetic polymers are now usual choice as elastomers in a base, with the most popular being co-polymers of styrene-butadiene and isobutylene-isoprene as well as poly (isobutylene), polyisoprene and polyethylene (Tisdale & Wilkins, 2014). Regular chewing gum contains 20-30% of gum base while sugar-free ones has up to 30% base on average (Fritz, 2006; Tisdale & Wilkins, 2014). Amount and type of gum base determine textural properties of gum especially the stickiness and chewiness (McGowan et al., 2005). Gum base composition affects binding of flavor compounds. Especially polarity of gum base ingredients defines mechanism of binding (Sotsman et al., 2009). Accordingly, elastomer choice can also play an important role for aroma release of chewing gum. If affinity between elastomer and flavor compound is high, flavor is perceived during masticating for a longer time, which is a privileged parameter for the quality of a chewing gum. The solvent of elastomers is generally terpene resins. When terpene resins are used in lower amounts mastication characteristics are affected negatively. However, when used in higher amounts in this case gum stickiness to tooth surface increases.

A chewing gum base is a non-edible, inert and insoluble substance used as a support for the soluble portion of chewing gum which is suitable for human consumption (various sugars, polyols and flavors). When considering suitability of a material for production of chewing gum base, the degree of stickiness, elasticity and pliability are important factors. Pliability, elasticity and firmness of chewing gum during mastication in mouth are important quality parameters evaluated during grading of the product.

In general, chewing gum utilizes a combination of natural or synthetic elastomers such as polymers of limonene or other diterpenes with rosin-glycerol esters in the formulation (Tisdale & Wilkins, 2014). FDA approved the usage of gum-rosin-derived esters as a food additive in the chewing gum (Wang et al., 2011). It can be concluded that polyvinyl acetate is one of the key ingredients in a successful chewing gum base formulation due to its nontoxic nature and having physical characteristics and masticatory properties most suitable for chewing gum base manufacturing (Tisdale & Wilkins, 2014).

Texturizers or fillers are the low cost ingredients that modify the texture of gum base as well as help in processing. Some examples of texturizers are calcium carbonate, magnesium and aluminum silicate and magnesium. Use of certain texturizers such as calcium carbonate poses a problem in formulations that require addition of acidic flavors since acid readily reacts with calcium carbonate. This not only results in loss of acids but also can damage chewing gum packages and candy coated gums due to production of carbon dioxide gas. In such cases, talc is commonly used since it does not react when in contact with acids, however the cost is high (Raithore, 2012).

Concerning huge chewing gum consumption, 250 thousand tons of gum base waste arises per year, which is a significant environmental problem since this waste is non-biodegradable. In order to clean this waste, significant expenditures are made. Therefore, it is important to fabricate chewing gums with biodegradable compounds. While the primary focus of the various patents describing the process of gum base production has been on texture aspects, interest in creating a gum base material that is biodegradable and green product, has been gaining momentum, and has been the subject of many patents (Raithore, 2012). For instance, using zein as a gum base was tried due to its non-adhesive and biodegradable properties (McGowan et al., 2005). The results indicated that zein can be used as a gum base; however, more studies are required to optimize formulation and production processes of such natural chewing gums.

2.2.2. Water-soluble base

In water-soluble phase, sugar sweeteners (60%) such as dextrose, sucrose, fructose, maltose, dextrin, galactose and dried invert sugar can be used with corn syrups (18-20%), sugar alcohols (<1.0%), glycerin (<1.0%) and flavor (0.5-1.0%) for sugar chewing gum. Particle size of the sucrose is important in sensory properties of the end product. Large particles can result in gritty texture in the product. For sugar-free chewing gums, sugar alcohols (also act as bulking agent) (50-60%), glycerin (5.0-6.0%), flavor (1.0-15.0%) and high intensity sweeteners (0.01-3.0%) can be used (Potineni, 2007).

High-intensity sweeteners and polyols are widely used as sugar-free chewing gum ingredients owing to their sweetness and non-caloric characteristics (Siefarth et al., 2011). In addition, they are accepted as non-cariogenic substances (not promote the development of dental caries) since bacteria, e.g. *Streptococcus mutans*, can not use polyols as an energy source for their reproduction and growth. The sugar alcohols (polyols) involving sorbitol, mannitol, xylitol, maltitol, lactitol, hydrogenated isomaltulose and hydrogenated starch hydrolysates are typically used in sugar-free chewing gums (Potineni, 2007). Xylitol and menthol can be added to the formulation alone or in combination with different flavors (Santos, Carpinteiro, Thomazini, Rocha-Selmi, da Cruz, Rodrigues, & Favaro-Trindade, 2014). However, xylitol is commonly used in combination with lower cost polyols such as sorbitol, lactitol, or mannitol due to its relatively high cost. Polyols are used with high intensity sweeteners (aspartame, asesulfame K and thaumatin) since they are not as sweet as sucrose. Otherwise, low sweetness can be perceived by consumers, which adversely affects the attractiveness of the products. In some chewing gums, antioxidants are also added to the formulation. Chewing gum generally contains antioxidants such as BHT, BHA (Edin, Fida-Lassang, & Schmaltz, 2010) and tocopherols. Antioxidants are used in the formulation to protect some components present in gum base (Fritz, 1999).

2.3. Production Process

Figure 2 shows conventional production process of chewing gum. As seen, after treating gum base at temperature between 70 and 120 ºC, depending on the machinability, liquid plasticizer (e.g. glycerin, polyols) is added with or without emulsifier and they are mixed for 2-8 minutes. Then approximately two thirds of the colorants and sugar are added and the obtained mixture is kneaded for 1-4 min. After that the kneading/mixing levels are reduced and the rest of sugar is added. Then, flavor agent is added and mixing proceeds for 1-4 min. Depending on the formulation, if required, antioxidants, humectants and fillers are added and the mixture is kneaded/mixed for more 1-4 min. After rolling process, thinning and/or cutting processes take place. Regarding coated chewing gum, in this step, coating is applied by ingredients such as sugar powder (Fig. 2). The mixing and kneading period mentioned depend on structure of gum base, composition and type of chewing gums.

Machinability of gum base plays an important role in determination of production process. Generally, gum base is present in three forms which are blocks (6-10 kg), pellets and sheets (5 mm in thickness). When the sheet gum bases are used there is no need for softening or melting. For production of chewing gum, three methods exist namely; (i) Conventional/traditional method (Fusion), (ii) Freezing, grinding and tabletting and (iii) Direct compression method. Figure 3 summarizes the production methods, advantageous and disadvantageous aspects of these methods. As can be seen the methods are significantly differ from each other. Therefore, optimum production process could be determined considering chewing gum type, active ingredients and formulation. Frequent problems in the chewing gum production include the release of flavor compounds and product texture (Valduga et al., 2012).

3. Quality Parameters

There are three aspects that distinguish chewing gum from other food products; retention in mouth, period of mechanical impact applied by teeth and its remaining parts being thrown away after consumption. Main quality parameters of the chewing gum include flavor, texture and sensory properties. Especially, detailed understanding of the in-mouth release properties of odorants in chewing gum is extremely important for obtaining the product with high quality (Itobe et al., 2012).

3.1. Texture

Ingredients of chewing gum have an important role in textural properties of the end product as well as machinability of intermediate products. Resins are used in chewing gum bases in order to provide a cohesive body and strength, and most often include glycerol esters of gum rosin, terpene resins and polyvinyl acetate (Tisdale & Wilkins, 2014). McGowan et al. (2005) noted that addition of waxes to formulation results in improvement of sensory properties in terms of flavor release, shelf life, and texture. Crystallization of sugar or polyols results in deterioration in texture of the products. Therefore, amounts of sugars or polyols used in the formulation could be considered regarding textural characteristics. Otherwise, consumer acceptability of the products could be adversely influenced by crystallization.

Sugar-free products are very popular and sugar is replaced by polyols and high-intensity sweeteners during their production. This replacement both influences the release of flavor compounds and also product texture (Siefarth et al., 2011).

Elastomers play an important hydrophilic detackifier role by absorbing saliva and becoming slippery when the gum is chewed (Tisdale & Wilkins, 2014). Besides, emulsifier choice in chewing gum production should also be taken into consideration and emulsifier with hydrophilic-lipophilic balance (HLB) value between 1.6 and 7.0 should be preferred. Because in some cases, emulsifiers undertake plasticizer function. Emulsifiers provide a smooth surface for gum and reduce its adhesive nature as well as aid in mixing. They bring the normally incompatible constituents of the gum base together so that a single continuous and finely dispersed stable system can be formed. They may also help incorporation of flavors into the gum base to provide uniform flavor distribution, and also reduce stickiness of gum to teeth and lips (Raithore, 2012). Other ingredients such as waxes and plasticizers are used to improve the texture of gum bases so as to give a better chewing quality to gum. By softening the gum base, they also help in the blending procedure.

Physical properties of ingredients present in chewing gum formulations have also an impact on the textural properties. In this respect, sugar can be accepted as the most important ingredient. Despite a lack of systematic study, manufacturers of chewing gum have found that the particle size of sucrose does have impact on not only the manufacturing process but also on the final texture of the gum. Sizes below 40 μm are found to make the product firmer whereas those over 150 μm give a sandy texture (Raithore, 2012).

The interaction between texture and flavor, the influence of chewing gum texture on the release behavior of volatile compounds in terms of direction and level were investigated in different studies. The texture and moisture content of the food material can influence the intensity of forces applied during oral processing, such as chewing and swallowing, therefore, they have influence on the flavour release characteristics in both temporal and intensity dimensions (Blee, Linforth, Yang, Brown, & Taylor, 2011). Partitioning of flavor compounds is affected by the texture and composition of the food (Ovejero-Lopez, Haahr, Van den Berg, & Bredie, 2004). Texture and flavor interaction is complicated and affected by many factors simultaneously. By changing the proportion of flavors, the texture of the resulting gum product can vary (Raithore, 2012). Correlation between the texture and flavor release in chewing gum models were investigated in some studies (De Ross, 2003; Potineni & Peterson, 2008).

3.2. Flavor

As it is normally expected from chewing gum that it should release a proper amount of flavor over a longer duration when compared with the other products (Blee et al., 2011). Thereby, release period of flavor of chewing gum is considered as main evaluation quality criterion (Wong et al., 2009). Flavor is a more substantive quality parameter for chewing gum than for other food stuffs, because the flavor of chewing gum is strongly required with an excellent characteristics of in-mouth release such as immediate flavor impression, long duration of perception of odorants during chewing, excellent odor quality and appropriate intensity (Ovejero-Lopez et al., 2004; Itobe et al., 2012).

Considering the importance of flavor release in chewing gum, development of suitable analytical techniques to observe volatile release from chewing gum during production, storage and consumption periods has drawn attention (Wong et al., 2009) since the estimation of flavor release from complex food matrices like chewing gum is backbreaking (Siefarth et al., 2011). The mechanisms of flavor release and perception in chewing gum can be better understood by combining analytical methods that monitor the release profiles of key flavor stimuli near the receptors with sensory evaluation (Potineni & Peterson, 2008b). The flavor perception in chewing gum includes the releasing behavior of the corresponding flavor from the product and their transport via the retronasal route to the nasal cavity, where aroma perception takes place (Itobe et al., 2012). Firstly, receptors in mouth and nose sense the flavor of food and then produce signals. These signals are processed in the neural system (Davidson, Linforth, Hollowod, & Taylor, 1999). Mastication of chewing gum may elicit a regular pattern of velum opening and consequently volatile delivery to the upper airway as it is eaten (Blee et al., 2011). The process of aroma perception involves many steps. First, odorants are released from the chewing gum and diluted with saliva during chewing. They are then volatilized into the headspace of the oral cavity and transported through the retronasal route to the nasal cavity, where they interact with the receptors in the olfactory epithelium. The information about sensation are converted to electric signals by receptors. As a result of transportation of the signals to the brain the aroma is sensed. Therefore, the in-mouth release of each odorant during chewing would be affected by each step in the process (Itobe et al., 2012). Odorant release in mouth is also important for overcoming jungle mouth, which is one of the most attractive reasons for consumption of chewing gum in daily life.

Although flavorings exist in low concentrations (about 0.4% to 1.0%) in the final gum formula, it is the second in importance after gum base considering quality of the end product (Wong et al., 2009). The release of flavor compounds from chewing gum has been traditionally predicted in the flavor/gum industry based on thermodynamic parameters of log P (hydrophobicity and polarity indicator) or log cP (Gum Base-to-Water Partitioning Coefficient: vapour pressure and volatility indicator) (Potineni & Peterson, 2008a). These two parameters provide information about release properties of corresponding flavor compounds for chewing gum matrix.

Atmospheric pressure chemical ionization mass spectroscopy (APCI-MS), Proton Transfer Reaction (PTR)-MS and sensory time-intensity (TI) methods used to monitor release characteristics of volatile compounds in chewing gum systems. Additionally, in the study carried out by Zhang et al. (2014) and Wong et al. (2009) flavour release in chewing gums is studied by HS-SPME – GC/MS technique. Also, Niederer et al. (2003) studied the various thermodynamic parameters such as partitioning coefficients, activity coefficients, Henry constants, molar heat of solution between flavor compounds and gum bases by using Inverse Phase Chromatography (IGC). Greater affinity between the gum base and flavoring compounds results in slower release or lastingness during mastication and vice versa (Potineni & Peterson, 2008a). Therefore, optimization of gum base/flavor compound type used in the formulation is essential for the production of the chewing gum with desired quality in terms of flavor release.

In order to adapt the texture and release of flavor compound to those of conventional sugar-containing food products, knowledge of the physicochemical interactions between volatile constituents of a food matrix is of great importance (Siefarth et al., 2011). The distribution of the flavor compounds between the phases of chewing gum depends on the compound affinity for each phase and historically has been related to the compound hydrophobicity (Potineni & Peterson, 2008a). It appeared that the in-mouth elution of odorants from the chewing gum to saliva was the partition phenomenon between the hydrophobic chewing gum base and hydrophilic medium (saliva). Therefore, it can be presumed the hydrophobicity/hydrophilicity (polarity) of each odorant would have an influence on the amounts of eluted odorants from the chewing gum (Itobe et al., 2012). Harrison (2000) studied flavor release mechanism for different volatile substances considering log cP in chewing gum models and they found that flavor compounds having low log cP values were determined to release faster and deplete more quickly than ones having higher value. Sotsman et al. (2009) found that the release profile of volatiles from chewing gums was determined by the hydrophilicity of the volatiles. Relatively hydrophilic compounds (log $P<1.8$) were released fastest and reached their maximum in the first several min of chewing while compounds with log $P>1.8$ showed an increasing release continually over the entire chewing period. Uneven distribution of flavor compound during chewing could be accepted as quality defect, which can be eliminated by controlled release of flavor compounds through encapsulation.

Flavor in chewing gums could not be released completely, which may be associated with the matrix of the product. Findings related with chewed gum indicated that most of the aromatizer substances were still observed in the bolus (Krause et al., 2011). In the study carried by Yamano and Tezuka (1979) it was highlighted that after 10 min chewing 23-27% of the incorporated D-carvone and L-menthol had been released from the gum bolus, and after 60 min it was only 58-62%. In the other study, the effect of the flavor compound, gum hardness, chewing efficiency and presence of plasticizer on flavor release behavior was studied and it was concluded that after 30 min mastication 10-50% of the volatile flavor compounds were released depending on these factors mentioned (De Ross, 2003). Different researches were conducted to optimize flavor release for chewing gum. In the study performed by Santos et al. (2014), the analysis of Time-Intensity in chewing gum found that the release of xylitol and menthol can be controlled by microcapsules and by this way it is possible to prolong the cooling sensation. Also, by high encapsulation efficiency, menthol provided a long duration of flavor when applied in the chewing gum. The addition of saliva has important effects on the retronasal aroma release and their release profiles. Therefore further investigation will be needed in order to understand the influence of saliva (Itobe et al., 2012).

Non-equilibrium partition model was performed to monitor releasing mechanism of different hydrophobic compounds in the chewing gum model systems (De Ross et al., 1994). Linear interaction between the release of flavor compounds and log cP value was determined for the first 5 min (thermodynamic control). For longer chewing periods, the use of log cP was not appropriate due to low relation between log cP and flavor release. Flavor release after 5 min was more explained by diffusion and mastication efficiency.

In other studies, relation between gum sweetness and flavor sensation was also investigated (Davidson et al., 1999 and 2000). It is believed that the most substantial parameter for the duration of sensation of flavor intensity in the chewing gum is the rate of sweetness release regardless of volatile release (Krause et al., 2011). In other words, flavor is perceived for longer times when chewing gum has high sweetness level (Krause et al., 2011). Davidson et al. (1999) investigated the release characteristics of menthone and sucrose from chewing gum system where panelists evaluated mint flavor intensity over time. As a result of this study, correlation between reduction of mint flavor intensity and sucrose concentration with respect to time was reported. In another study, which was performed by Raithore (2012), the flavor release profiles for both aroma and high intensity sweetener compounds were highest for the sample formulated with the least water-soluble polyol (mannitol) and lowest for sample with the most water-soluble polyol (sorbitol). Unique polyol-flavor interactions were reported by Raithore (2012) concerning flavor delivery; the aroma compounds were mainly influenced by the polyol type whereas the high intensity sweetener by particle size.

Also, increasing intensity of flavor release is more proportional to bolus weight in low-fat foodscompared to high-fat foods, which can result from selective adhesion of fat to the oral cavity surfaces and by this way effective surface area required for the lipophilic flavor release can vary (Linforth, Blissett, & Taylor, 2005). However, flavor release of compounds depend on chemical structure of them, namely, their hydrophobic or hydrophilic nature since according to the previous studies, positive correlation between retention of lipophilic compounds and fat content was mentioned in dairy desserts (González-Tomás, Bayarri, Taylor & Costell, 2007; Van Ruth, de Witte, & Rey Uriarte, 2004). On the contrary, greater concentrations of fats and oils typically lead to reduction in volatility of hydrophobic odorants like long-chain aldehydes (Keršiene, Adams, Dubra, De Kimpe, & Leskauskaitė, 2008). The fat's mechanism of action on food flavor is very complex (Arancibia, Castro, Jublot, Costell, & Bayarri, 2015). It was reported that fats affect the flavor release due to the two factors: (i) being a solvent for lipophilic flavor compounds and (ii) its effect on texture (Arancibia et al., 2015). De Roos (1997) reported that among the food ingredients lipids have the greatest effects on the partitioning of flavor compounds between corresponding materials and the gaseous phase.

3.3. Sensory

The sensory response to an added flavor in chewing gum is mainly influenced by the rate and extent of the in-mouth flavor release which depends on the partition between the different phases (chewing gum-saliva-air) and mass transfer rate (Harrison, 2000; Itobe et al., 2012). Mouthfeel is the sensation produced by physical stimulation of receptors in the mouth such as by texture or temperature (Raithore, 2012). The taste and aroma perceptions were tested individually, but then the amount in-nose remains fairly constant over long periods of time (Davidson et al., 1999).

To achieve an understanding of the dynamic process of food flavor perception, it is necessary to apply time-resolved research methods (Ovejero-Lopez et al., 2004). A time-intensity (TI) study is a widely used relevant tool to observe the intensity variance. In this method, the association between intensity of the corresponding material and duration of its perception is described graphically (McGowan et al., 2005). Quality of the chewing gums are commonly evaluated by Time-Intensity (TI) sensory analysis due to its effectiveness (Santos et al., 2014,; Davidson et al., 1999; Druizer, Bloom, & Findlay, 1996; Guinard, Zoumas-Morse, Walchak, & Simpson, 1997; McGowan & Lee, 2006; Neyraud, Prinz, & Dransfield, 2003; Ovejero-Lopez, Bro, & Bredie, 2005), since it provides beneficial results for the monitoring of changes in flavor intensity as a function of time (Delarue & Loescher, 2004).

Regarding solid foods, mass transfer occurs between the solid matrix and the mouth liquid phase (saliva) and then the direction of transfer is towards to the gas phase (breath). In this circumstances, the amount and structure of matrix and flavor found in mouth can play an important role in aroma release, while the matrix degradation level and the effective surface area are influenced by mastication intensity and duration (Linforth et al., 2005). The findings implied that variation in gum composition can be analyzed by both instrumental and sensory methods, procuring suitable results (Ovejero-Lopez et al., 2004). Blee et al. (2011) investigated the variation *in vivo* volatile release between panelists consuming different types of confectionery. They noted that the chewing gum gave maximum constituent release, which was affected by chewing intensity in oral processing and volatile delivery. Krause et al. (2011) reported that investigating the flavor release by a kind of chewing device can provide repeatable and robust results than that carried out by panelists.

Flavor release analyses in minted chewing gum can be carried out using instrumental and sensory tests (Ovejero-Lopez et al., 2004) and in general agreement was observed between APCI-MS and TI observations. However, although by means of *in vivo* studies it can be possible to obtain information about the interaction between flavor release and perception duration, the applied methods have drawbacks which can be eliminated by artificial chewing devices (Krause et al., 2011). For instance, the volatile delivery differences observed across the panel may represent variations in velum opening as a result of differences in mouth movement (Blee et al., 2011).

Since eating is a dynamic process, the influence of texture on flavor release and sensation was studied by *in vivo* studies (Raithore, 2012). In the study of Ovejero-Lopez et al. (2004), it was concluded that the retronasal concentration and sensibility of the peppermint oil was affected by its concentration level (0.5-2% w/w) added to the gum. The sweeteners' (sorbitol or xylitol) effect was less apparent. In the other study, sweetness and peppermint perceptions in chewing gum were determined using dual-attribute and it was found that faster release of sweetness increased the duration and intensity of sweet perception, as well as the duration of peppermint flavor (Druizer, Bloom & Findlay, 1996). In the study of Davidson et al. (1999), delivery of sucrose and menthone in chewing gum system during masticating was determined in-mouth and in-nose, respectively. They indicated that the panelists' perception of mint flavor followed sucrose release rather than menthone release. The temporal analysis of the chemical stimuli, with simultaneous TI analysis provided unequivocal evidence of the perceptual interaction between nonvolatile and volatile flavor compounds from chewing gum (Davidson et al., 1999).

Color is one of the decisive sensory parameters affecting consumer acceptability of the products. In addition, the stability of the coloring compounds against mouth condition is also important since chewing gum can be repeatedly used in a day. Therefore, stable coloring compounds could be used in chewing gum formulations. Encapsulated coloring agents could provide color stability for a longer time. In the study performed by Chranioti et al. (2015), the chewing gum samples produced with saffron and beetroot colouring extracts encapsulated in gum Arabic-modified starch showed the greatest $a*$ (for beetroot) and $b*$ (for saffron) values indicating a better protection.

4. Opportunities for Delivering Bioactive Compounds

Chewing gum is different from other food products in terms of the fact that it is chewed for long periods without being swallowed in mouth (Davidson et al., 1999). As known, it is not directly eaten, it is masticated with teeth in mouth (Yang et al., 2011), and different compounds present in the chewing gum can be absorbed to body during chewing. During the chewing process, bioactive compounds are released from chewing gum matrix into saliva. After release, they could reach the stomach by absorption or swallowing mechanisms (Chandran et al., 2014).

There are very limited studies (Yang et al., 2004; Abbasi et al., 2009; Santos et al., 2014; Charanioti et al., 2015) on chewing gums evaluating use of microcapsules in food science and technology field. However, it has substantial advantages when compared with the other confectionery products which are produced at elevated temperature levels. Chewing gum is the most suitable media for encapsulated and un-encapsulated bioactive substances due to its fabrication conditions where extreme heat and moisture conditions are not applied (Santos et al., 2014). These characteristics of chewing gum enable the food industry to produce functional, nutritional and dietetic chewing gums (Abbasi et al., 2009).

In the study performed by Yang et al. (2004), chewing gum containing catechins were prepared by applying a novel dispersion and hot-melt fluid bed coating method. The effect of varying levels of Eudragit® coating to the granules on the prolonged release of catechins from chewing gum was investigated. They noted that PVC was not an ideal material for sustained release of catechins, which were added chewing gum as tea polyphenols. Improved formulations (Yang et al., 2004) and process optimization of chewing gum are demanded so that controlled and sustained release of bioactive compounds can be achieved. Also, for essential oil, microencapsulation technology is required to achieve controlled release of target compound (Xiao, He, & Zhu, 2014). One of the obvious applications of microencapsulated ingredients (particularly acids) is their insertion in chewing gum where microcapsules can be ruptured by mucus (chemical activity) or by chewing (physical rubs) to release their contents in a controlled manner in order to achieve a long-lasting acidic taste (Abbasi et al., 2009).

Another advantage of chewing gums in delivering bioactive compounds is that generally chewing gums are not swallowed and they are low calorie products. Therefore, in recent years when obesity is a big problem throughout the world, such products providing less energy to body have attracted attention in terms of delivering functional compounds.

Selection of encapsulation techniques and encapsulating agents is very important according to the results of the study performed by Xiao et al. (2014) for encapsulation efficiency to increase stability of bioactive compounds. The other aim of microencapsulation is to reduce probable interactions between ingredients to maintain desired color, flavor and texture characteristics of the foodstuffs during shelf life (Abbasi et al., 2009).

As mentioned above, water content of gum base is low, and the matrix of the gum can preserve the active compounds from extrinsic factors such as oxygen, light and humidity, which can reduce or eliminate chemical degradation reactions and growth of microorganisms (Maggi et al., 2013). In addition, shelf life and stability can further be improved by optimization of process and ingredients. The impact of sodium lactate addition and storage conditions on the stability of chewing gums was investigated by Valduga et al. (2012). They noted that sodium lactate incorporation to the formulation in concentrations of 1.08 % on dry basis improved the stability of the product, as well as the use of lactic acid in place of citric acid.

In the studies related with development of functional chewing gums, physical and chemical properties of bioactive compounds should be investigated considering characteristics of foods used as a carrier of bioactive compounds. For instance, owing to the high hydrophilic characteristics of chewing gums, the strong attraction leads to deprivation of volatile organic compounds upon concentration (Wong et al., 2009). Also, chewing gums are composed of many different ingredients which have tendency to interact with themselves and with the active substance (Maggi et al., 2013). Particle size of the bioactive compound could be regarded as another factor. The particle size of the active ingredient should be kept below approximately 100 μm to avoid unpleasant gritty feeling during chewing (Chandran et al., 2014).

In the studies about improvement of functional foods, determination of needs and characteristics of target consumer groups and consumption patterns is of capital importance. Hearthy et al. (2014) noted that older children consume more chewing gum than younger children and adolescents chew much more than older adults in Europe.

The results obtained from studies related with improvement of medicated chewing gum can direct researches carried out in food technology area. As a result of both *in viv*o and *in vitro* studies, although drug release performance during chewing had less variability during storage, it should be controlled since gum matrix is semi-solid and may be affected by mastication which can significantly influnce the delivery characteristics of the drug (Maggi et al., 2013). Also, the taste of active ingredient must be within the acceptable limits (Chandran et al., 2014).

Release of most water-soluble components from chewing gum was sustained not more than 5 min, which is not sufficient for the effective treatment (Yang et al., 2004). Also, Delarue & Loescher (2004) found out that some consumers chew for few min and then they substitute it with fresh gum. On the contrary other ones may chew the same gum for half-a-day or more. So that, low dose active ingredients are the prime candidates for the formulation of functional chewing gums (Chandran et al., 2014).

Mineral and vitamin deficiencies could be eliminated by incorporating of these ingredients in the chewing gum. Stability and extractability of them from gum matrix to saliva can be improved by using encapsulated forms of them. Important bioactive compounds such as fatty acids, carotenoids, tocopherols, flavonoids, polyphenols, phytosterols are hydrophobic nature (Kris-Etherton et al., 2002); therefore, their transportation to saliva from chewing gum matrix could be a problem. However, encapsulation enables the water solubility of these substances.

In recent years plant-based volatile aroma compounds have attracted interest due to their antimicrobial, insecticides and fungicides characteristics (Schwab, Davidovich-Rikanati, & Lewinsohn, 2008; Boulogne, Petit, Ozier-Lafontaine, Desfontaines, & Loranger-Merciris, 2012); therefore, they can be used to improve the shelf-life (Ayala-Zavala, González-Aguilar, & Del-Toro-Sánchez, 2009) and health benefits of food products (Keiler, Zierau, & Kretzschmar, 2013). Some of the plant sourced volatile compounds were hexanal, hexyl acetate, neral, geranial, vanillin, terpinen-4-ol, linalool, α-terpineol (Ayseli & Ayseli, 2016). Such volatile compounds could be used in chewing gum formulation due to their health benefits and aroma providing characteristics.

Health benefit effects of microalgae were reported and they included polyunsaturated fatty acids (Eicosapentaenoic acid, γ-linolenic acid, arachidonic acid, docosahexaenoic acid), sterols (brassicasterol, stigmasterol), pigments (phycocyanin, phycoerytrin, β-carotene, astaxanthin, lutein, zeaxanthin, canthaxanthin), proteins, enzymes and vitamins (Vitamins C, K, B_{12}, A and E) (de Jesus Raposo, de Morais, & de Morais, 2013). Therefore, microalgae can be added at concentrations depending on the quality of chewing gum to improve nutritional and functional properties of the products.

During production of chewing gum with functional property, uniform distribution of the corresponding bioactive compound is critical. Therefore, production method should be determined considering this situation. In fusion method, high temperature levels are applied for melting of gum base, which causes deterioration of bioactive compounds. If the bioactive compound is added at lower temperature levels the homogeneity of it in chewing gum is very difficult due to high viscous character of the sample. Regarding the methods mentioned, direct compression method is suitable for the manufacturing of chewing gum for delivery aims.

5. Conclusion

In food science and technology area, awareness of potential uses of chewing gum is scarce due to lack of scientific studies conducted about chewing gum. There are wide range of chewing gum benefits from freshening breath to acting as a pleasant way to take vitamins and medicine. However, to improve these functions of chewing gum, detailed understanding of chewing gum ingredients, production process, interaction of flavor or bioactive compounds release behavior with its texture and ingredients are necessary. Therefore, importance of chewing gum should be appreciated to take the advantage of this enjoyable confection which can become a tailor-made product for various human needs. According to the results it could be concluded that chewing gum is a promising confection providing the most hospitable environment for bioactive compounds due to the mild production conditions and having the longest duration of remaining in mouth among other foods. Therefore, more scientific studies should be conducted in food science and technology area to disclose potentials of chewing gum.

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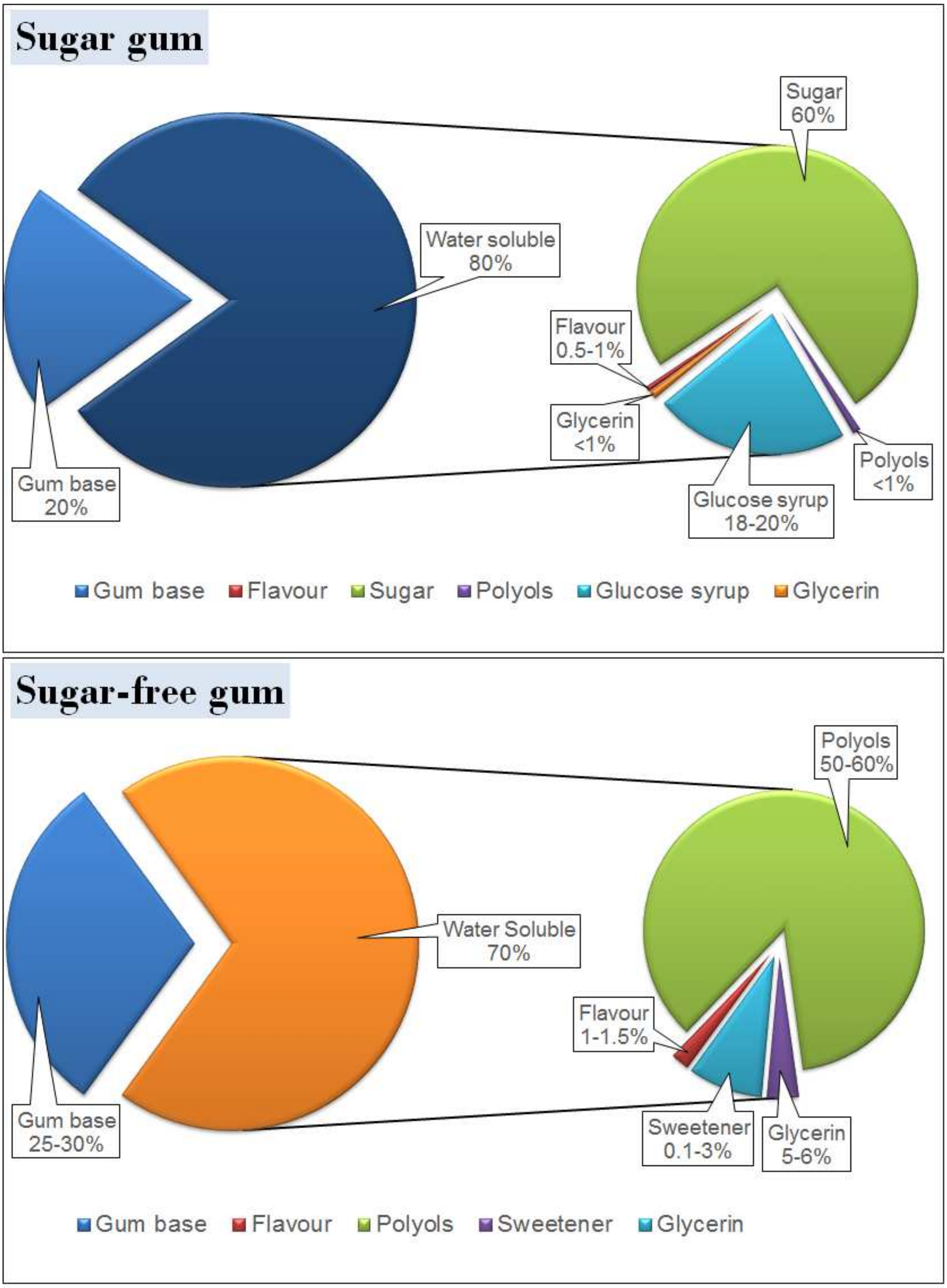

Fig. 1. Average quantitative formulation of sugar and sugar-free chewing gum components

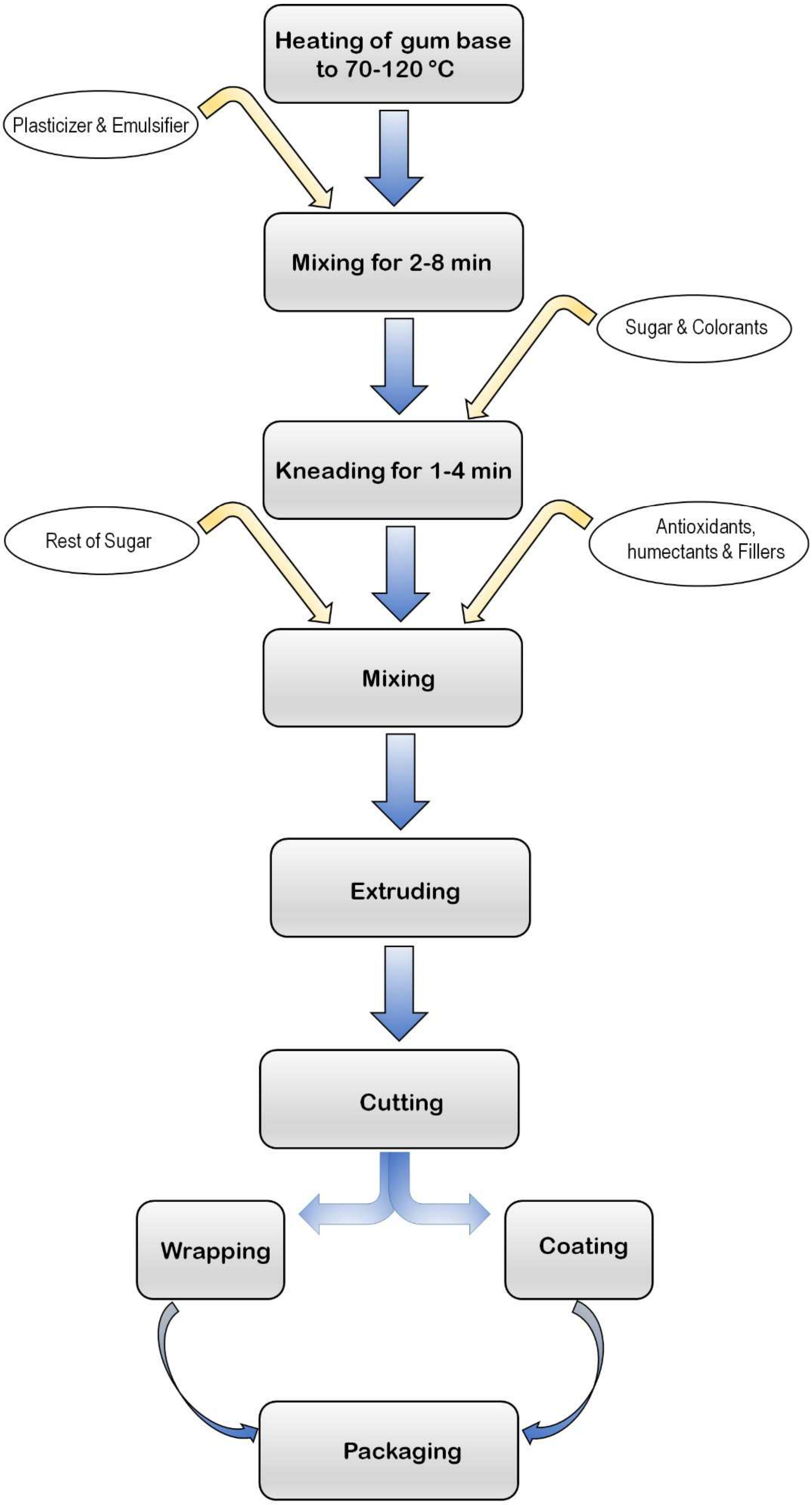

Fig. 2. Production process of chewing gum

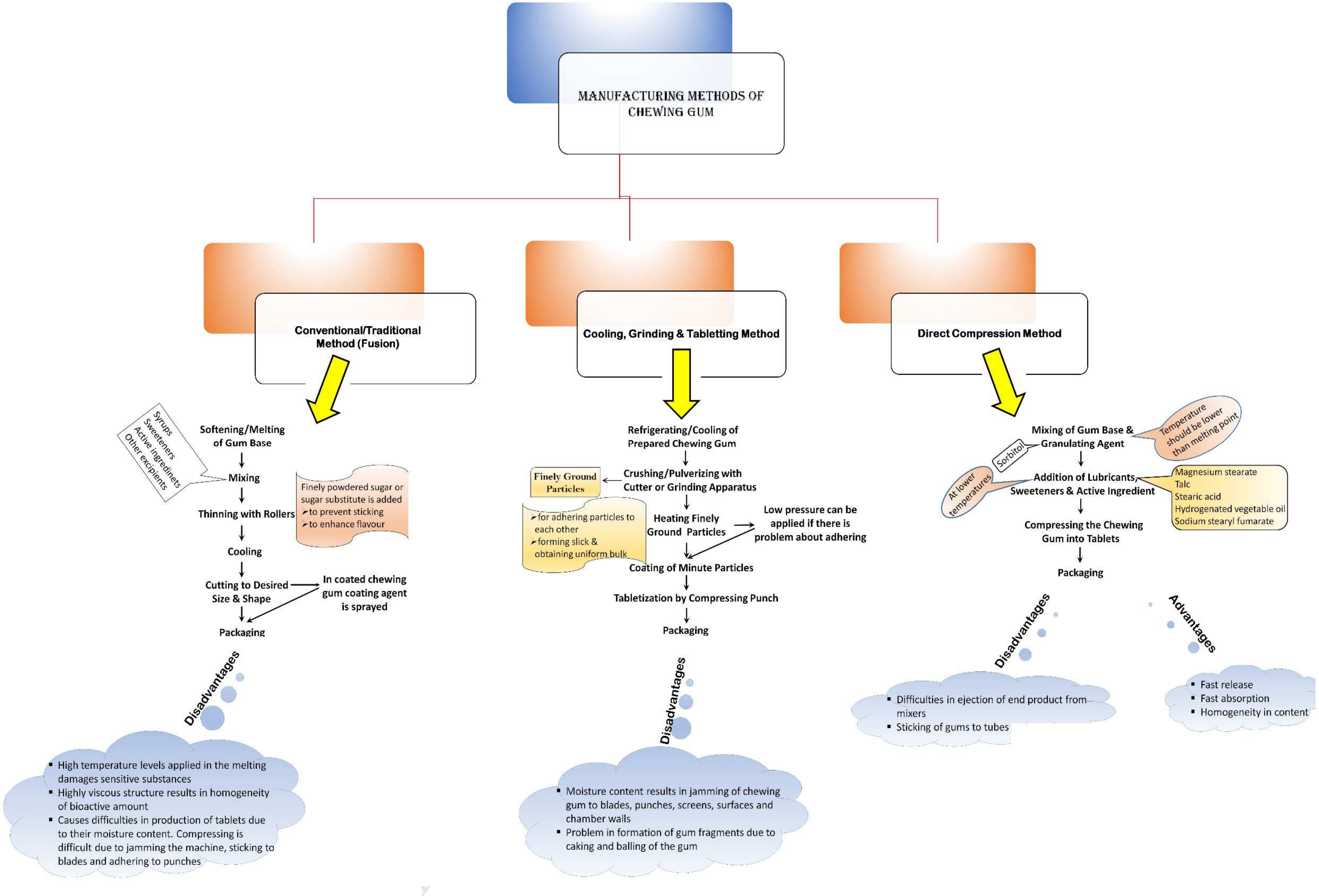

Fig. 3. Production methods of chewing gum and their advantages and disadvantages

Highlights

Chewing gum is one of the most popular confectioneries worldwide.

It is an unusual food that remains in the mouth for long periods.

It provides hospitable environment for encapsulated and unencapsulated bioactives.

Potential uses of chewing gum is scarce due to lack of scientific studies.