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Influence of hydrocolloids in chocolate confections: A review.

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ABSTRACT

Chocolate confections have been consumed from the ancient times. Various organic and synthetic ingredients have been used to enhance the functional and nutritional properties of chocolate. Use of hydrocolloids for the same have set a benchmark in the confectionery industry. Hydrocolloids play various roles in the development of high quality chocolates. As a binding agent it increases the adhesiveness of the hard coating in panning technique. It forms edible films to serve as a moisture barrier and provide glossy appearance of the chocolate. Addition of appropriate concentrations of hydrocolloids enhanced the texture of chocolates. As a fat replacer it influenced in producing low calorie chocolates without affecting the form V ($\beta 2$)fat polymorphic structure of the chocolate. It has also been reported to produce sugar-free chocolates with enhanced health benefits. In addition to all these properties hydrocolloids play a major role in controlling the viscosity and improving the flow behaviour of chocolates. This review centres on the influence of hydrocolloids in chocolate confections.

Keywords: Hydrocolloid; Chocolate rheology; Edible film; Binding agent; Fat mimetic; Sugar substitute

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INTRODUCTION

Chocolate the most popular confection of all time was supposed to have been the maiden to be consumed by the Aztec kings. It is a high energy product consisting of carbohydrates and fat as the main sources of energy. Its unique texture, flavour and aroma are the key factors for its expanding consumption around the world [1][2].Lifestyles are becoming increasingly inactive, forcing consumers to arrive at healthier food products. Since children are the prime consumers of chocolate the concern to develop high quality and healthiest chocolates has been one of the dominant factors in the latest research trends, prompting studies of ways to produce low calorie, sugar-free chocolates besides the texture, flavour and aroma. This paved way for the application of hydrocolloids in chocolate confectionery.

Food hydrocolloid is widely used in food industry as thickeners, gelling agents, foaming agents, edible coatings, emulsifiers and stabilizers [3] to modify the food attributes, *viz*., rheology, binding of water, emulsion stabilization, prevention of ice recrystallization and enhancement of organoleptic attributes [4][5].This review focuses on the wide range of applications that hydrocolloids perform in chocolate confections including functional attributes, *viz*., chocolate rheology, film-forming attributes, binding properties, texture properties and nutritional attributes, *viz*., fat replacers and sugar substitutes.

*CACAHUATL*TO *XOCOLATL*

Xocolatl, theNahuatl term of chocolate is the cocoa liquor derived from the super fruit cacao (*cacahuatl* – the Nahuatl term) of *Theobroma cacao* [6] [7]. Chocolate manufacturing is comprised of multifarious steps starting from cocoa bean processing to liquid chocolate making [8] which is been depicted in Fig. 1. One of the prime requirements in food manufacturing is the quality of food. A food product is said to be consumable only if it satisfies the following specifications, *viz*., functional, biological, nutritional, sensorial, ethical and 'authentic' characteristics. Correspondingly, a high quality chocolate should satisfy certain characteristics which have been influenced by food hydrocolloids.

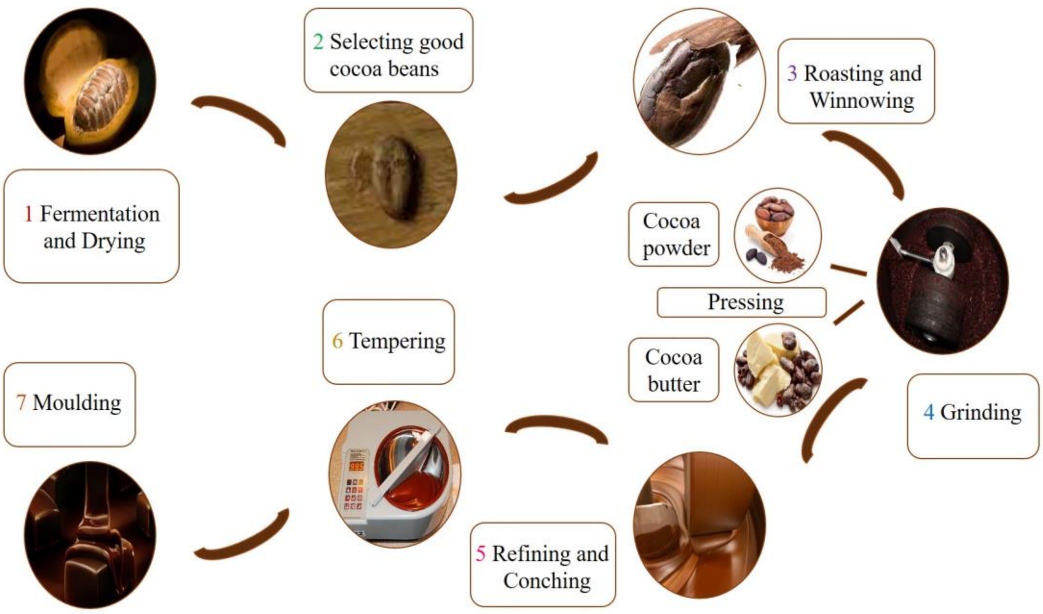

Fig 1: Chocolate making process.

FUNCTIONAL ATTRIBUTES

Rheology

Rheology is a branch of science that deals with the study of deformation and flow of matter. Depending upon the relationship between shear stress and the rate of strain, chocolate is defined as non-

Newtonian fluid [9]. Chocolate rheology is generally determined in chocolate production using two factors: yield stress and apparent (plastic) viscosity. Yield stress is associated with the minimum shear stress required to begin the chocolate flow [10]. Chocolate with a high yield stress is used for placing streaks on candies and producing chocolate crumbs. On the contrary chocolate with low yield stress is used as an edible coating on cookies. Plastic viscosity is associated with the stress required to keep the chocolate flowing. It is used to determine the thickness of chocolate coating and the size of pumps for pumping the chocolate [8].The determination of rheological properties of chocolate has been a prime factor in producing the desired product. It can be determined by several mathematical models, *viz*., Bingham, Herschel–Bulkley and Casson models [10].

The Casson model is a conventional structure based and the chiefly used rheological model for determining the non-Newtonian flow of chocolate with a yield stress [11]. Hydrocolloids have been used for controlling the rheological attributes of the same. Manifestly, viscosity amelioration varies depending upon the type and concentration of hydrocolloid used.

β-glucan-rich hydrocolloid (C-trim30) has been found to increase the viscosity of chocolate with increasing concentrations of C-trim30. Based on the results from the Cassonmodel the chocolate viscosity increased rapidly. In this study up to 10% of C-trim30 was found to produce softer chocolates as its viscosity increased at higher concentrations. [12].

In a comparative study of the effects of carboxymethyl cellulose, xanthan gum, high methyl-esterified pectin, low methyl-esterified pectin, sodium alginate and iota-carrageenan with two different concentrations (0.5 and 1.0% w/w) on the rheological characteristics of white, milk and dark chocolates, sodium alginate and xanthan gum increased the viscosity of milk chocolate, whereas carboxymethyl cellulose and low methyl-esterified pectin increased the viscosity of dark chocolate. Among all the hydrocolloids sodium alginate and iota-carrageenan increased the chocolate viscosity of all the three types of chocolate. Evidently the concentration of the hydrocolloid affects the rheological behaviour of the chocolates. [13].

A combination of two hydrocolloids enhanced the flow behaviour of the chocolate compared to the use of single hydrocolloids. The interaction between xanthan gum/corn starch blends controlled the flow of chocolate. The casson viscosity was found to increase within the range of 5% to 15% hydrocolloid blends concentration [14]. Furthermore, the interaction between xanthan gum/guar gum blends led to the development of highly viscous chocolate with the concentration of hydrocolloids ranging from 10% to 15% [15].

Inulin and polydextrose has been found to enhance the flow properties of chocolate at various concentrations, whereas maltodextrin showed improvement only at lower concentration (<20%) [16]. Chocolate viscosity increased with increase in the degree of polymerization of inulin withal [17]. In another study, it has been proved that inulin/polydextrose mixture eventuated in significantly higher casson viscosity. [18].

Hydrocolloids in the form of emulsion and hydrogel dispersion improved the flow of the chocolate. Chitosan a linear polysaccharide along with fumed silica was found to control the viscosity of chocolate [19]. Agar in the form of 50% aqueous phase microgel dispersion has been found to enhance the rheological behaviour of chocolate [20].

Texture

Food palatability is elucidated as the hedonic impact of food to the palate. It is determined by certain organoleptic properties, *viz*., flavour, texture, appearance, sound, and temperature. Among all properties food palatability is determined significantly by the flavour and texture [21]. Flavour is associated with components having a low molecular weight, discerned through chemical pathway. On the contrary, texture is associated with components having high molecular weight, discerned through the physical pathway. Texture is an amalgamation of mechanical and thermal attributes discerned in both oral and pharyngeal phases of the feeding process. Texture is determined by the dispersing, aggregation, and alignment of food constituents, including molecules, particles, cells, and organizations. It has been aforementioned that texture governs more than 30% of food palatability [22].

Mouth feel is used to refer the tangible facets of texture perception during consumption [23]. After consumption, the mouth senses post mastication of the consumed food. Therefore, texture environs the tangible facets connected with the food, food remnant and human palate. Food texture can be enhanced by the inclusion of hydrocolloids in food products [24]. Texture of chocolate is perceived by different qualities, *viz*., hardness, thickness, smoothness and creaminess. It has been reported that the maximum peak force is a measure of chocolate hardness. [25] [26]. Penetration probing test conducted for chocolates containing *β*-glucan-rich hydrocolloid (C-trim30) elucidated that the maximum peak force withstood by the chocolates decreased the hardness of chocolate with increasing concentration of C-trim30 resulting in softer texture of the chocolate [12].

Hardness is the main quality of chocolate texture. The texture of the chocolate has been enriched by the addition of xanthan gum/guar gum blends as gel networks [15].

Concentration of hydrocolloid plays a vital role in determining the chocolate texture. Based on this criteria higher concentrations of polydextrose and maltodextrin produced softer chocolates [16].

Inulin a naturally occurring polysaccharide was found to produce hard chocolate [16]. On the contrary inulin HPX with a degree of polymerization ≥ 23 produced softer chocolate.[27].

Edible film

Edible film is an aqueous solution that forms a coat on the food product. It has been used for various purposes, *viz*., to enhance the shelf life of food products, as a moisture barrier, to improve the food quality, to reduce food damage [28][29], as a fat and oil barrier and to enhance nutritional value of food [30].

Edible film is generally applied in liquid form. It is necessary to produce a continuous layer of film to obtain the desired product [31][29]. In chocolate confections edible films has been used to enhance the texture quality, *viz*., glossiness and brightness and to serve as a moisture barrier.

Hydrolyzed collagen is a form of collagen produced by the process of hydrolysis. In this study hydrolyzed collagen has been reported to improve various properties of edible film, *viz*., tensile strength, water vapour permeability, film morphology and texture along with pectin in chocolate panned products. Pectin has been used to prevent phase separation and low emulsification of the products.

The tensile strength of the film increased with increase in hydrolyzed collagen concentrations. It has been observed that hydrolyzed collagen concentrations greater than 15% were more effective. Higher concentrations of hydrolyzed collagen produced homogeneous structures and lower water vapour permeability ranging from 0.32 to 0.63 g mm m^{-2} h^{-1} kPa^{-1}. The edible film formed enhanced the brightness of the product [32].

Binding agent

Adhesion is defined as the physical and chemical binding of food matter with the food covering. Poor adhesion of the food coating leads to poor organoleptic properties of the food product [33]. Binding Agents are substances that helps a mixture hold its shape or remain bound together as an adhesive. In chocolate confection binding agents are used in the panning process for holding the centre.

Panning is a process used in confections for the formation of a shell or sugar coating [34]. Hydrocolloid plays a vital role as binding agent in the panning technique for the preparation of dragee – a bite sized colourful confection with hard coating. A dragee pan is used for the same (Fig. 2). [8].

Among various hydrocolloids gum arabic has been predominantly used as the binding agent in chocolate confections. In the panning process gum arabic is being used as an adhesive to reinforce the sugar coating of a dragee. Gum arabic is a low viscous polysaccharide that forms a thick syrup at high concentrations ranging from 55-60%. This low viscosity is responsible for its structural branching, leading to the formation of a globular molecule. When hydrated in water the branching prevents it from micelle formation by reducing the intermolecular hydrogen bonding. As a result, the solution gets tacky at high concentrations leading to the formation of a weak film that gives brittle texture when dried.

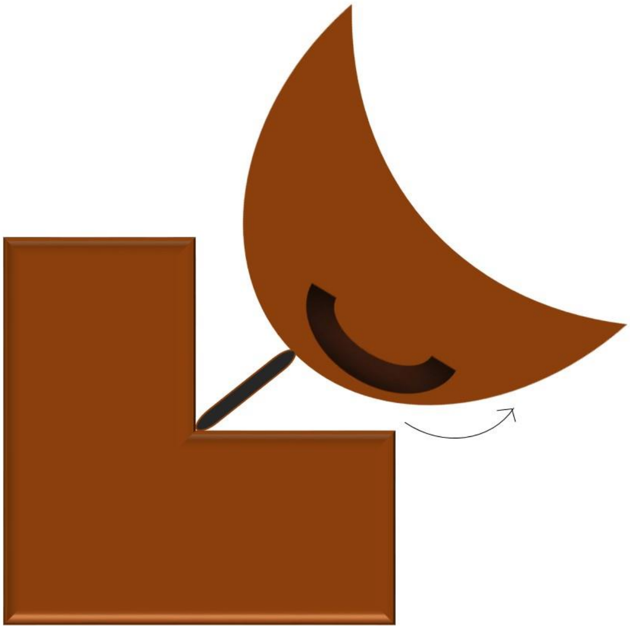

Fig 2: A dragee pan with the material to be panned.

The addition of 3.5% gum arabic to the syrup containing 64.5% maltitol (sugar alcohol) and 32% water has been found to bind and strengthen the sugar coating that holds the centre, *viz*., nuts and chocolate. [35].Besides gum arabic, other hydrocolloids have also been used as a binding agent by different chocolate companies around the world (Table 1).

Table 1: List of hydrocolloids used as a binding agent in dragees

Panning Type	Chocolate Name	Company	Hydrocolloid
Sugar panning	Smarties	Nestle	Modified starch
	Galaxy minstrels	Mars	Starch
	M&M	Mars	Gum arabic
	Skittles	Mars	Modified corn starch
	Gems	Cadbury	Gum arabic
	Pebbles	Cadbury	Modified maize and tapioca starches, gum arabic
	Snow bites	Cadbury	Modified tapioca starch
Chocolate panning	Revels	Mars	Modified starch
	Maltesers	Mars	Pectin
	Whoppers	Hershey	Tapioca dextrin
	Mighty Malts Malted Milk Balls	Necco	Gum arabic
	White maltesers	Mars	Pectin
	Whispers	Cadbury	Starch
	Nutties	Cadbury	Gum arabic
	Milk chocolate Drops	Hershey	Modified corn starch, gum arabic
	Cookies n creme drops	Hershey	Modified corn starch, gum arabic
	Milk chocolate with almonds (pieces)	Hershey	Gum arabic

NUTRITIONAL ATTRIBUTES

Fat mimetic

Fat mimetic are substances that emulate organoleptic attributes of fats and oils [36]. Addition and production of low calorie food has been the emerging food processing technology. Calorie dense substances, *viz*., fats and oils can be replaced by hydrocolloids. Hydrocolloids as a fat mimetic have great importance in the confectionery industry.

Fat polymorphism is the ability of fat to exist in more than one crystal form. Cocoa butter the fat component of cocoa bean has a complex polymorphism. It has the ability to crystallize in multifarious forms. The different crystalline forms are defined by differences in the distances between the glyceride chains and their angle of tilt. Cocoa butter has two important attributes, *viz*., the melting behaviour and flavour development [37]. Cocoa butter consists of six polymorphic crystalline forms (Table 2) [38]. Among all the six forms, Form V (*β*2) (melting point 34-35°C) has been reported to produce stable and well-tempered chocolate. Hydrocolloids have the potential to prevent fat bloom and to produce low calorie chocolate without affecting the fat polymorphism and melting behaviour of the chocolate. *β*-glucan-rich hydrocolloid (C-trim30) used as a fat replacer has been reported to reduce the calories from fat thereby producing healthy chocolates [12].

Table 2: Six polymorphic forms of cocoa butter

Polymorphic form	Phase	Melting point
Form I	sub-*α*	16-18°C
Form II	*α*	22-24°C
Form III	*β*2'	24-26°C
Form IV	*β*1'	26-28°C
Form V	*β*2	32-34°C (stable form)
Form VI	*β*1	34-36°C (fat bloom)

The combination of hydrocolloids results in developing well-tempered chocolate. The novel fat replacer developed by the xanthan gum/corn starch blends was reported to produce low calorie chocolate [14].

A comparison of different concentrations of xanthan gum/guar gum blends showed that the concentrations of the blends influenced the melting profile. It also reported that the polymorphic form V (*β*2) (melting point 34-35°C) has not been affected at 5% concentration [15].

Hydrocolloids are also been found to replace a certain percentage of cocoa butter in the form of emulsion and hydrogel. Chitosan along with fumed silica replaced 50% of cocoa butter in the chocolate [19]whereas agar replaced 80% of cocoa butter in the chocolate [20]. Concentrations of different hydrocolloids at which it does not impinge on the polymorphic form V (*β*2) of chocolate is depicted as a pie chart (Fig. 3).

Sugar substitute

Sugar substitutes are food additives that possess sweet taste like that of sugar, whereas nutritive sweeteners are substances that substitute both the physical bulk and sweetness of sugar [39] [40].Sugar is the key ingredient in confections. On the contrary, it possesses various disadvantages, *viz*., tooth decay, sugar bloom, texture and reduction of bioactive compounds. In the current scenario sugar - free chocolates are more diverse and provide high levels of quality.

To develop sugar – free chocolates with desirable quality both sweeteners and bulking agents should be added. Low-digestible carbohydrate polymers also known as hydrocolloids serve as both sweetener and bulking agent [41].

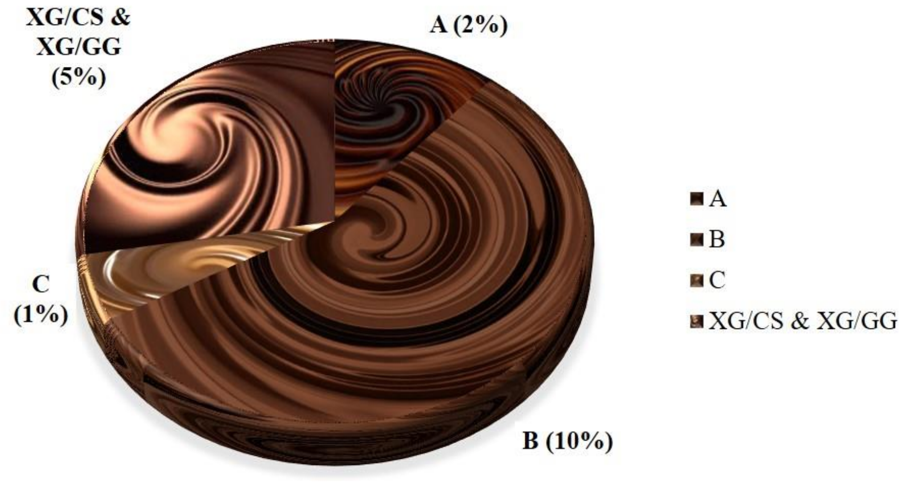

Fig 3: Concentrations of hydrocolloids at which it forms well-tempered chocolate. A= agar; B= *β*-glucan-rich hydrocolloid (C-trim30); C= chitosan; XG/CS & XG/GG= xanthan gum/corn starch & xanthan gum/guar gum.

The effect of sugar substitute is not only dependent on the type of hydrocolloid used, but also on the concentrations present. Inulin and polydextrose mixtures with the concentration of 75.3594% (polydextrose) and 24.6406% (inulin) has been found to produce sugar – free chocolates with enhanced health benefits [42]. Inulin and oligofructose has also been reported to reduce the sugar content and produce sugar – free chocolates [43].

CONCLUSION AND FUTURE RESEARCH

There are only certain foods that people feel passionate about. From ancient times it has been elucidated that there has been craze for chocolate. Chocolate is well known for its antioxidant property. Besides, chocolate has been found to possess various health issues.

Food hydrocolloids - the naturally occurring polysaccharides have been used to overcome these problems. As aforementioned in this review, hydrocolloids enhances the production of low calorie chocolates without affecting the fat polymorphism. It has also been reported that hydrocolloids enhances the chocolate viscosity which is the noteworthy attribute to produce well-tempered chocolate. From a textural point of view, hydrocolloids are considered to produce softer sugar-free chocolates at optimized concentration. Meticulous research is required in utilizing the hydrocolloids to produce chocolates that surmount certain health aspects to ensure a healthy lifestyle.

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REFERENCES

[1] Aidoo, R. P., Depypere, F., Afoakwa, E. O., &Dewettinck, K. (2013). Industrial manufacture of sugar-free chocolates e applicability of alternative sweeteners and carbohydrate polymers as raw materials in product development. *Trends in Food Science and Technology*, 32, 84-96.

[2] Afoakwa, E. O. (2010). *Chocolate science and technology*. Oxford, UK: Wiley-Blackwell Publishers Inc.

[3] Williams, P. A., & Phillips, G. O. (2000). Introduction to Food Hydrocolloids. In G. O. Phillips, & P. A. Williams (Eds.), *Handbook of Hydrocolloids* (pp. 1–19). CRC Press: Boca Raton.

[4] Hoefler, A. C. (2004). *Hydrocolloids*. Eagen Press: Minnesota.

[5] Nussinovitch, A. (1997). *Hydrocolloid Applications*. Chapman and Hall: London.

[6] Ann Bingham & Jeremy Roberts (2010). *South and Meso-American Mythology A to Z*. Infobase Publishing (p. 19).

[7] Fowler, M. S. (1999). Cocoa beans: from tree to factory. In Beckett, S. T. (3rd Ed.), *Industrial Chocolate Manufacture and Use* (pp. 8–35). Oxford: Blackwell Science.

[8] Stephen T Beckett (2008). *The Science of Chocolate* (2nd edition.).The Royal Society of Chemistry: Thomas Graham House, Science Park, Milton Road, Cambridge CB4 0WF, UK, 252.

[9] Anandha Rao, M. (1999). *Rheology of Fluid and Semisolid Foods Principles and Applications.*Aspen Publishers, Inc: Gaithersburg, Maryland.

[10] Sokmen, A., &Gunes, G. (2006). Influence of some bulk sweeteners on rheological properties of chocolate. *LWT*, 39, 1053-1058.

[11] Joye, D. D. (2003). Shear rate and viscosity corrections for a Casson fluid in cylindrical (Couette) geometries. *Journal of Colloid and Interface Science*, 267, 204-210.

[12] Suyong Lee, GirmaBiresaw, Mary P. Kinney & George E. Inglett (2009). Effect of cocoa butter replacement with a *β*-glucan-rich hydrocolloid (C-trim30) on the rheological and tribological properties of chocolates. *Journal of the Science of Food and Agriculture,* 89, 163-167.

[13] Joao Dias, NunoAlvarenga& Isabel Sousa (2015). Effect of hydrocolloids on low-fat chocolate fillings. *Journal of Food Science and Technology*, DOI 10.1007/s13197-015-1841-0.

[14] Syafiq, A., Amir, I. Z. & Sharon, W. X. R. (2014). Mixture experiment on rheological properties of dark chocolate as influenced by cocoa butter substitution with xanthan gum/corn starch/ glycerin blends. *International Food Research Journal*, 21(5), 1887-1892.

[15] Amir, I.Z., Sharon, W.X.R. &Syafiq, A. (2013). D-Optimal mixture design on melting and textural properties of dark chocolate as affected by cocoa butter substitution with Xanthan gum/Guar gum blends. *International Food Research Journal*, 20(4), 1991-1995.

[16] Farzanmehr, H., &Abbasi, S. (2009). Effects of inulin and bulking agents on some physico-chemical, textural and sensory properties of milk chocolate. *Journal of Texture Studies*, 40, 536-553.

[17] Briggs, J. L., & Wang, T. (2004). Influence of shearing and time on the rheological properties of milk chocolate during tempering. *Journal of American Oil Chemists' Society*, 81, 117-121.

[18] Roger Philip Aidoo, Emmanuel OheneAfoakwa& Koen Dewettinck (2014b). Rheological properties, melting behaviours and physical quality characteristics of sugar-free chocolates processed using inulin/ polydextrose bulking mixtures sweetened with stevia and thaumatin extracts. *LWT - Food Science and Technology*, DOI 10.1016/j.lwt.2014.08.043.

[19] Thomas S. Skelhon, Nadia Grossiord, Adam R. Morgana & Stefan A. F. Bon (2012). Quiescent water-in-oil Pickering emulsions as a route toward healthier fruit juice infused chocolate confectionary. *Journal of Materials Chemistry*, 22, 19289-19295.

[20] Thomas S. Skelhon, Patrik K. A. Olsson, Adam R. Morgana & Stefan A. F. Bon (2013). High internal phase agar hydrogel dispersions in cocoa butter and chocolate as a route towards reducing fat content. *Food & Function*, 4, 1314-1321.

[21] Kohyama, K. (2005). Textural characteristics. In K. Nishinari, H. Ogoshi, K. Kohyama, & T. Yamamoto (Eds.), *Handbook of texture creation* (pp. 185-191). Tokyo: Science Forum, (in Japanese).

[22] Nishinari, K. (1996). New texture modifiers for foods, interactions among different food hydrocolloids and their potential of application. *Kagaku to Seibutsu*, 34, 197-204, (in Japanese).

[23] Guinard, J. X. &Mazzucchelli, R. (1996). The sensory perception of texture and mouthfeel. *Trends in Food Science &*Technology, 7, 213–9.

[24] Van Olphen, H., &Mysels, K. J. (1975*). International Union of Pure and Applied Chemistry. Commission I.6: Colloid and surface chemistry*. La Jolla, CA: Theorex.

[25] Liang, B., &Hartel, R. W. (2004). Effects of milk powders in milk chocolate. *Journal of Dairy* Science,87, 20–31.

[26] Ali, A., Selamat, J., Man, Y. B. C. &Suria, A. M. (2001). Effect of storage temperature on texture, polymorphic structure, bloom formation and sensory attributes of filled dark chocolate. *Food Chemistry,* 72, 491–497.

[27] Hebette, C. L., Delcour, J. A., Koch, M. H., Booten, K., Kleppinger, R., Mischenko, N., et al. (1998). Complex melting of semi-crystalline (*Cichoriumintybus* L.) inulin. *Carbohydrate Research*, 310, 65-75.

[28] ChidanandaiahKeshri, R. C., Sanyal, M. K., Kotwal, S. K., &Sudhan, N. A. (2005). Quality changes in enrobed/coated products during storage. *Indian Food Industry*, 24, 57-61.
[29] Kester, J. J., &Fennema, O. R. (1986). Edible films and coatings: a review. *Food Technology*, 40, 47-59.
[30] Balasubramaniam, V. M., Chinnan, M. S., Mallikarjunan, P., & Phillips, R. D. (1997). The effect of edible film on oil uptake and moisture retention of a deep-fat fried poultry product. *Journal of Food Process Engineering*, 20, 17-29.
[31] Greener, I. K., &Fennema, O. R. (1989). Barrier properties and surface characteristics of edible bilayer films. *Journal of Food Science*, 54, 1393-1399.
[32] Fadini, A. L., Rocha, F. S., Alvim, I. D., Sadahira, M. S., Queiroz, M. B., Alves, R. M. V., & Silva, L. B. (2013). Mechanical properties and water vapour permeability of hydrolysed collagen-cocoa butter edible films plasticised with sucrose. *Food Hydrocolloids*, 30, 625-631.
[33] Suderman, D. R., & Cunningham, F. E. (1980). Factors affecting adhesion of coating to poultry skin. Effect of age, method of chilling, and scald temperature on poultry skin ultrastructure. *Journal of Food Science*, 45, 444-449.
[34] Joseph R Perrozzi(1958). *U.S. Patent No. 2,851,365*. Washington, DC: U.S.
[35] Marceliano B. Nieto, Greg Andon (2013). *European Patent No. EP2666368* (*A1*). Munich, Germany: European Patent Office.
[36] Duflot, P. (1996). Starches and Sugars Glucose polymers as sugar/fat substitutes. *Trends in Food Science & Technology*, 7, 206.
[37] Johnston, G. M. (1972). Fats and Processes Used In Manufacturing Chocolate and Confectionery Coatings. *Journal of the American Oil Chemist's Society*, 49, 462-467.
[38] Willie, R. L. &Lutton, E. S. (1966). Polymorphism of Cocoa Butter. *The Journal of the American Oil Chemist's Society*, 43, 491-496.
[39] Kroger, M., Meister, K., & Kava, R. (2006). Low-calorie sweeteners and other sugar substitutes: a review of the safety issues. *Comprehensive Reviews in Food Science and Food Safety*, 5, 35-47.
[40] Salminen, S., &Hallikainen, A. (2002). Sweeteners. In A. L. Branen, P. M. Davidson, S. Salminen, & J. H. Thorngate (2nd Ed.), *Food additives* (pp. 447-475). New York: Marcel Dekker Inc.
[41] Jamieson, P. (2008). The sugarfree toolbox-bulk ingredients and intense sweeteners. *The Manufacturing Confectioner*, 88(11), 33-46.
[42] Roger Philip Aidoo, Emmanuel OheneAfoakwa& Koen Dewettinck (2014a). Optimization of inulin and polydextrose mixtures as sucrose replacers during sugar-free chocolate manufacture – Rheological, microstructure and physical quality characteristics. *Journal of Food Engineering*, 126, 35–42.
[43] Ana Belscak-Cvitanovic, DrazenkaKomes, Marko Dujmovic, Sven Karlovic, MatijaBiskic, MladenBrncic, &DamirJezek, (2015). Physical, bioactive and sensory quality parameters of reduced sugar chocolates formulated with natural sweeteners as sucrose alternatives. *Food Chemistry*, 167, 61-70.