REVIEW

Nutrafoods (2018) 17:33-40
DOI 10.17470/NF-017-1017-1

Received: October 10, 2017
Accepted: December 18, 2017

Technological and quality parameters of reduced-calorie chocolates: a review

Sadaf Nazir[1], Z.R.A.A. Azad[1]

Correspondence to: Z.R.A.A. Azad - zrazad@gmail.com

ABSTRACT

The preference for healthier and convenience food products has resulted in a demand for reduced-calorie chocolate which has 20% fewer calories than conventional chocolate but the same brightness, aroma, flavour and hue. The fat replacers used in reduced-calorie chocolate are usually derived from vegetable oils and/or polysaccharides. The vegetable oils include palm oil, corn oil and soybean oil, while the polysaccharides include carrageenan, guar gum and locust bean gum. Gums are considered healthier than vegetable oils but result in a weaker texture. Therefore, vegetable oils are often used in combination with gums to improve the rheological characteristics of reduced-calorie chocolate. Sucrose substitutes include sugar alcohols, dietary fibres, syrups and natural/artificial sweeteners. Sucralose is by far the preferred artificial sweetener because of its stability at higher temperatures. The incorporation of fat and sugar replacers increases the viscosity and slipperiness of reduced-calorie chocolate. Also, reduced-calorie chocolate is more bitter and less sweet than conventional chocolate.

Keywords
Chocolate
Fat replacer
Vegetable oil
Polysaccharide
Rheology

Introduction

Chocolate is a high energy product, with sugar and fat providing most of the calories. It is consumed more for pleasure than for nutrition, and has a unique taste, flavour and texture. Recent studies have highlighted the natural chemical components of chocolate and its health benefits. Modern chocolate was created by John Cadbury by emulsification in the UK in the 19th century [1].

Dark, milk and white chocolate is manufactured today. Most commercially available cocoa powders contain 10–24% fat, with a 10–12% fat range preferred [2–4]. The high sugar and fat content of chocolate lessens the positive bioactive effects of cocoa. In recent years, the chocolate industry has responded to a demand for low-calorie, low-sugar and low-fat chocolate believed to be better for overall and heart health. However, a food without fat has very little taste, so the fat is replaced with sugar or a sugar substitute, resulting in a low-calorie product. Reduced-calorie chocolate tastes just like regular chocolate and has the same benefits but fewer calories.

The amount of reduced-calorie chocolate manufactured over the past decade has dramatically increased. Chocolate is a dispersion of around 70% fine particles such as cocoa powder, sugar substitutes and milk solids in a continuous phase consisting of fat substitutes, depending on the formulation. Each sugar or fat substitute has a specific effect on the flow and physical characteristics of the chocolate. Various studies have examined the rheological properties, melting behaviours and other characteristics of reduced-calorie chocolates made from inulin, sucralose and polydextrose, bulking agents, and sweeteners such as stevia and thaumatin extracts. The fat content and the fineness of the cocoa liquor also directly influence the viscosity of the product [5, 6].

[1]Department of Food Technology, Faculty of Engineering and Interdisciplinary Sciences, Jamia Hamdard, New Delhi India, 110062
Tel. +91 9810810816

Fat and sugar substitutes for reduced-calorie chocolates

Fat replacers and bulking agents

Fat substitutes derived from polysaccharides or vegetable oils are incorporated into chocolates to reduce the calorie content. The addition of plant polysaccharides decreases the glycaemic index of the product, while the addition of vegetable oils reduces fat digestion and absorption in the gut. Some fat substitutes are used as a simple replacement for saturated fat, while others are used to improve taste and mouthfeel while also reducing calories. The most commonly used fat replacers are carrageenan, guar gum, inulin, palm oil, soybean oil and olive oil [7–9]. In the European Union, six basic source oils are permitted as non-cocoa vegetable fats (cocoa butter equivalents) in chocolate: palm oil, shea oil, illipe butter, sal oil, kokum gurgi and mango kernel oil. Vegetable oils like palm oil have a higher saturated fatty acid content than lard, beef tallow and butterfat [10].

Fat-substituted chocolates have a nice dry, fluffy texture. They also have melt-in-the mouth characteristics and a longer shelf-life. In addition, vegetable oils act as carriers for fat-soluble vitamins (A, D, E and K). They also provide energy and essential linoleic and linolenic acids [11]. The fatty acid profile plays a key role in the physio-chemical properties. Palm kernel oil (PKO) is a high-quality food-grade oil used in chocolates instead of cocoa butter replacers, which are very expensive. Koushki *et al* reported that palm oil contains a healthy mixture of saturated and unsaturated fatty acids [12]. Norulaini *et al* demonstrated that the carotenes in palm oil have the highest bioavailability of all plant carotenes [13]. Palm oil has been used to deliver provitamin (A) carotenes to at-risk children: low doses of red palm oil protect against vitamin A deficiency and blindness. Carotenes also have several other physiological functions such as antioxidant activity, immune function enhancement and anti-cancer properties [14].

McIvor *et al* studied diets rich in non-absorbable carbohydrate (fibre) [15]. Particulate fibres such as cellulose have little or no effect, but soluble viscous fibres such as guar gum are effective in normalizing carbohydrate intolerance in patients with non-insulin-dependent diabetes mellitus (NIDDM). The impact of particulate fibre consumption has been studied in detail, but little was known about the toxicity of guar gum.

Therefore, eight adults with NIDDM consumed at least 30 g of guar gum daily for 16 weeks without any changes in haematological, hepatic or renal function, lipid, protein or mineral metabolism, or electrolyte balance. It was concluded that consumption of 30 g of guar gum every day for a prolonged period has no serious consequences. Consequently, guar gum is of interest for inclusion in weight loss and diabetic diets and especially in confectionary such as chocolate. Guar gum is thermogenic (increasing the basal metabolic rate) [16] and its low digestibility means its use as a filler promotes satiety and slows digestion, thus lowering the glycaemic index of the food. In the late 1980s, guar gum use in several weight-loss products was heavily promoted [17].

Chan *et al* examined carbohydrate bulking agents which are partially or wholly non-digestible (i.e., non-metabolizable) and do not contribute to the taste of the product [18]. These materials include polydextrose, lactitol, Palatinit (isomalt), Palatinose (isomaltulose), polyglucose, polymaltose, carboxymethylcellulose, carboxyethylcellulose, arabinogalactan and microcrystalline cellulose. Partially or wholly non-digestible carbohydrate bulking agents are widely used in diet foods (usually in the range of 25–60%).

Vuorinen-Markkola *et al* examined the effect of guar gum on glycaemic control, serum lipid and lipoprotein profiles in mildly hypercholesterolaemic patients with insulin-dependent diabetes [19]. Guar gum was consumed four times a day for 6 weeks in a randomized and double-blind trial. Fasting blood glucose and haemoglobin decreased significantly during the trial, but the diurnal glucose profile was unchanged. Serum low-density-lipoprotein (LDL) cholesterol decreased by 20% and the ratio of LDL cholesterol to high-density-lipoprotein cholesterol decreased by 28% during the 6 weeks. No changes were seen in the placebo group. It was concluded that guar gum can improve glycaemic control and decrease serum LDL cholesterol concentrations in mildly hypercholesterolaemic insulin-dependent diabetic patients. Such reports support the use of plant polysaccharides as fat substitutes in confectionary such as chocolate.

Sucrose replacers

Harrigan [9] and Haumann [20] reviewed dietary factors implicated in the aetiology of some chronic degenerative diseases. Peters repeated the dietary advice that people with diabetes should eliminate simple sugars (primarily sucrose) from their diet [21]. Most commercial sweeteners include high fructose corn syrup, inulin, honey and/or molasses. Sugar alcohols such as isomalt, maltitol, xylitol, lactitol, sorbitol and mannitol are also used. In addition, artificial sugar substitutes include saccharin and aspartame or sucralose.

Health-conscious consumers want to improve their nutritional habits but not decrease satisfaction [22, 23]. Warshaw *et al* stated that the demand for sugar-free products is increasing [24]. New and high-quality sweeteners have been developed. Sugar replacers taste very like sucrose but their absorption by the body is extremely slow and incomplete [25].

Some non-calorie sugars lose sweetness at high temperatures but sucralose has excellent stability during cooking and baking, and even ultra-high temperature pasteurization (UHT) [26]. Ketelsen *et al* reported that sucralose has a sweetness profile very similar to that of sugar and does not interact with other ingredients in food [27].

In another study, sucralose was also reported to have similar sweetness to sugar [28]. Sugar replacers in chocolate improve the overall nutritional profile of the product by reducing calories and thus decreasing the risk of obesity. The use of sugar replacers or sucrose replacers meets the demand for food products suitable for patients with diabetes. The thermal stability of sucralose allows it to be used at high temperatures by the food industry and by the consumer at home. It also remains stable in food products for extended periods of storage, even at low pH [29]. Sucralose is formed by inversion of configuration at carbon-4 from the gluco to the galacto analogue; the resulting molecule, 1,6-dichloro-1,6-dideoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D-galactopyranoside, like sucrose and other disaccharides, is small (MW ~400), highly water-soluble and lipophobic [30]. The presence of chlorine at specific sites on the sucralose molecule stabilizes the glycosidic linkage against enzymatic hydrolysis. Sucralose is only absorbed by passive diffusion and is not broken down for energy and is, therefore, non-caloric [31]. Studies have also shown that it is unlikely to interact with commonly used food ingredients such as preservatives and added nutrients [32].

A claim that a food product is light or sugar-free can only be made if it provides less than 40 calories or less than 0.5 g of sugar per serving; a claim that it is ‘reduced sugar’ or ‘less sugar’ can only be made if it has at least 25% less sugar per serving compared with a standard serving. All chocolates produced with natural sweeteners have 25% or more less sugar compared with standard chocolate, and so can be labelled ‘reduced sugar’ products. The fructose, glucose and sucrose in a 40 g serving of such chocolate will provide 4 kcal/g, sugar alcohols will provide 2.4 kcal/g, and inulin and oligofructose will provide 2.0 kcal/g [33].

Overall acceptability

The taste of chocolate depends on the balance between the sweetness of sugar and the bitterness of the cocoa liquor. Relatively small variations can have a significant effect on that balance. A chocolate product that is too bitter can be corrected by using cocoa liquor with a milder flavour. However, chocolate with a bitter taste can often also be improved by merely increasing the sweetness of the product. Similarly, a chocolate product that is too sweet can be improved by using stronger-flavoured cocoa liquor. Additional flavour ingredients such as vanillin are often also used.

Various trends

Chocolate spreads were developed by incorporating two different soybean oil margarines [34], leading to omega 3 enrichment. A sucrose-free milk chocolate was also developed [35]. A method for reducing the viscosity of chocolate was devised by Cully [36].

Chan developed reduced-calorie chocolate confectionary in which non-digestible polyol fatty acid polyester replaced the natural fat, and an artificial sweetener plus a partially or wholly non-digestible carbohydrate bulking agent replaced sugar [18].

Keme *et al* produced sugar-free diet and/or teeth-sparing chocolates using a sugar-free crumb [37].

John *et al* described a low-fat product consisting of 20.0–24.5% (w/w) fat or fat substitute, and non-fat solids comprising nutritive carbohydrate sweetener, non-fat cocoa solids and an edible emulsifier [38]. They further described the formulation of and process for producing a low-fat chocolate.

Despland *et al* developed a process to produce a sucrose-free milk chocolate with the taste and mouthfeel of traditional milk chocolate [35].

Talbot determined that vegetable fats similar to cocoa butter in triglyceride composition and cocoa butter equivalents can be added to chocolate without having a significant effect on texture [39]. Cocoa butter replacers such as lauric fats, palm kernel and coconut oils, are used to completely replace cocoa butter.

Thompson *et al* determined that there was no difference between conventional, diabetic and diabetic/reduced-calorie laboratory-developed milk chocolate as regards brightness, cocoa aroma, cocoa butter aroma and cocoa flavour [40].

Gomes studied bulking agents used as sucrose substitutes in the formulation of chocolate, with the aim of obtaining a diet product with 25% fewer calories than standard formulations containing sucrose, with good sensorial acceptance [41].

The bulking agents used in this study were polydextrose, inulin, fructo-oligosaccharides, lactitol and maltitol. Sucralose was used as a high intensity sweetener. The chocolates were analyzed for moisture content, particle size and rheological properties. The moisture content varied from 1.23% to 2.12%, while particle size varied from 19 to 24 mm. The formulations containing polydextrose, polydextrose and lactitol, and polydextrose and maltitol were selected for sensory analysis due to their good technological performance. No statistically significant difference (p>0.05) in the three evaluated formulations was found in terms of aroma, hardness, melting in the mouth or flavour. Nor was there a statistically significant difference (p>0.05) in the intention to purchase the three chocolate formulations, although a preference was shown for the formulation containing polydextrose (32.60%) and maltitol (15.57%).

El-Kalyoubi *et al* developed novel technologies for fat substitution. Chocolate spreads were formulated by replacing palm oil with 25%, 50%, 75% and 100% cotton seed oil [42]. The specifications depend on the type of chocolate and its intended use [43]. Physical, chemical and rheological properties such as particle size distribution, apparent viscosity, flow behaviour constants and hysteresis behaviour, and sensory properties such as smoothness, melt-rate, cocoa flavour and milk flavour, were measured in soft chocolate samples. Rheological properties indicated that replacement with 25% palm oil resulted in chocolate most like the control sample and that increasing the ratio of replaced fat had a significant effect on rheological properties. Sensory evaluation revealed that chocolate made from 25% palm oil was as acceptable as conventional chocolate.

Jeyarani *et al* developed chocolate spreads by incorporating 85% soybean oil (M1) and a 1:1 blend of soybean oil and coconut oil (M2) with commercial palm stearin [34].

The heat resistance of the chocolate was increased by incorporating stearic acid-rich fractions into the cocoa butter. The moisture and fat content were 5–6.1% and 31.4–32.8% for formulations made with skim milk powder and 21.5–24.7% and 15.6–21.4%, respectively, for those made with fluid skim milk (FSM). Rheological studies of FSM spreads showed higher G″ (loss modulus) than G′ (storage modulus) values, indicating better spreadability. The products had an acceptability score of 8.3–10.5 (maximum score: 15). Fat extracted from spreads prepared using M1 and M2 contained 43.9% and 22.3% linoleic acid and 2.1% and 4.4% linolenic acid, respectively, and was free from trans-fats, while a commercial hazelnut spread had 9.8% linoleic acid but did not contain linolenic acid.

El-Hadad *et al* replaced butter fat in conventional chocolate spread with 20%, 40%, 60%, 80% and 100% red palm oil [44]. Chocolate spreads made from 20% red palm oil were as acceptable as conventional chocolate spread (100% butter fat). Replacement led to a significant increase in tocopherols, tocotrienols and carotenes. The samples had not deteriorated in quality after 6 months.

Chocolate made with sucralose was similar to conventional milk chocolate (with sucrose) and chocolates made with stevioside [45]. Sucrose replacement with high-intensity sweeteners and bulking agents with partial fat replacement increased hardness [46]. However, compared with conventional chocolate, that made with high-intensity sweeteners, sucralose and stevioside was more bitter and had a bitter aftertaste, although this increase was smaller for sucralose than for stevioside [25].

Nazir *et al* developed a novel calorie-controlled and sugar-free dark chocolate enriched with guar gum [47]. Results showed that guar gum in combination with palm oil is a suitable replacement for cocoa butter and does not affect cocoa butter bioactivity.

Health implications

Cocoa and chocolate products have generated significant interest owing to their association with various protective and therapeutic properties, and at least 45 human studies have been performed [48]. The flavonoids and antioxidants present in cocoa help control blood pressure. Among the hundreds of compounds in cocoa are a group of polyphenolic compounds or flavonoids. These flavonoids/procyanidins account for 35% of all polyphenols in cocoa. Procyanidins consist of flavan-3-ol(–)epicatechin (epicatechin) and its polymers. Evidence from epidemiological studies suggests that diets high in polyphenols reduce the risk of cardiovascular disease and related chronic conditions. Chocolate flavonoids are potent antioxidants capable of protecting LDL from oxidation. Cocoa procyanidins were found to exhibit immune-modulatory effects by inhibiting proliferation and suppressing the production of interleukin-2 and human T-lymphocytes. The anti-proliferative effects of cocoa polyphenols using human colon-cancer cells were also examined [49].

Methylxanthines

Cocoa products contain theobromine, caffeine and traces of theophylline. Depending on the degree of fermentation and the type of cocoa powder, the theobromine and caffeine contents will vary from 1.5% to 3.0% and from 0.1% to 0.5%, respectively. Despite its close chemical resemblance, theobromine does not exert the stimulant effect caffeine has on the human nervous system [50].

Energy

Interest in the caloric value of food products is currently high because of consumers' sensitivity to diet. The amount of cocoa powder in a product is generally low in comparison to sugars and fats. The caloric value of cocoa powder is low, so cocoa powder contributes little to a product's total caloric value and thus has minimal effects on total energy intake. The caloric values of cocoa liquor and cocoa butter in chocolate are, of course, higher but are reduced by the use of fat and sugar substitutes.

Decrease in blood pressure and increase in insulin sensitivity

Researchers in Italy recently fed 15 healthy people 3 ounces of dark chocolate, which contains no flavanol phytochemicals, each day. After 15 days, systolic blood pressure had dropped in the study subjects [51].

Rheological properties

The demand for sucrose replacers and cocoa butter substitutes for making reduced-calorie chocolates has increased dramatically over recent years. These substitutes affect the flow (rheological) and physical characteristics of the final product. Physical and textural properties are used to classify products and also affect food behaviour during processing, storage, packing, handling and consumption [52]. The properties of molten chocolate are strongly affected by particle characteristics, including particle dispersion and fat crystals formed during chocolate cooling and solidification. Rheological properties are usually quantified by measuring yield stress and apparent (plastic) viscosity. Yield stress denotes the transition between pseudo-solid and pseudo-liquid behaviours, while plastic viscosity affects flow characteristics, filling of rough surfaces, coating and sensory properties. Viscosity is determined by particle size distribution, composition and processing method. Chocolates with a high viscosity have a sticky mouthfeel. The apparent yield stress of molten chocolate can be described by various mathematical models [53, 54].

Rheological properties are influenced by particle size distribution and ingredient composition, which in turn affect final texture, melting profile and processing. Most of the solid ingredients are about 1 mm or more in diameter. The tongue can detect particles above 0.03 mm in diameter, which impart a gritty texture to the chocolate. Very fine particles less than 0.005 mm in diameter are produced by milling. Coating these particles with fat makes the chocolate less viscous and allows it to flow better and melt more easily so that it does not coat the mouth [4].

It is very important that the sucrose and lactose in the finished crumb are highly crystallized. This reduces the amount of amorphous glassy sugar available to trap fat, thus decreasing the amount of fat needed to obtain the required chocolate viscosity. Organoleptic characteristics also depend on the fineness of the cocoa nibs to ensure maximum free fat, minimum viscosity, and appropriate texture and flavour. Nibs should be 25 μm smaller in diameter than the eventual fineness of the chocolate in order to reduce equipment wear, increase throughput, and reduce product viscosity [55, 56].

Saturated fats containing trisaturated triglycerides can crystallize during the tempering process, thus affecting chocolate properties. Four (palm, shea, sal and mango kernel) of the six commonly used oils (palm, shea, sal, mango kernel, illipe butter and kokum gurgi) are usually fractionated to concentrate SOS triglyceride for equivalence to cocoa butter. The significant amount of trisaturated triglycerides in palm oil also has to be removed.

Maheshwari and Reddy studied the use of kokum fat (*Vateria indica*) as a cocoa butter improver in chocolate formulations. The high stearic acid content in kokum fat is useful for increasing solid content, for raising the melting point, and decreasing tempering time [57]. The authors found that chocolate containing 18.2% kokum fat had significantly increased shear stress and viscosity compared with chocolate prepared using less kokum fat. These results may be due to the fact that kokum fat crystallizes at 30°C.

Schantz and Rohm studied the effect of an optimized blend of the emulsifiers lecithin and polyglycerol polyricinoleate on the flow parameters of melted chocolate [58].

Nebesny and Dorota compared the effects of soybean lecithin on sucrose-free, dark and milk chocolate masses sweetened with isomalt and aspartame with those on chocolate mass sweetened with sucrose [59]. Dark and milk chocolate masses containing isomalt had a higher viscosity than sucrose-sweetened chocolate. Also increased lecithin resulted in decreased viscosity, adversely affecting organoleptic and flow properties.

Nebesny *et al* developed a sucrose-free chocolate formulation containing live lactic acid bacteria [59]. Sokmen and Gunes studied the effects of different bulk sweeteners, such as maltitol, isomalt and xylitol, and their particle size distribution on the rheological properties of molten chocolate [53]. Abbasi and Farzanmehr evaluated the rheological characteristics of prebiotic chocolate formulations containing different amounts of polydextrose and maltodextrin (0–100%) along with sucralose [60]. Aidoo *et al* studied sugar-free chocolates made from inulin and polydextrose mixtures and sweetened with stevia and thaumatin extracts and investigated their rheological properties, melting behaviours and other physical characteristics [5]. The authors found that when sweetened with stevia or thaumatin, sugar-free chocolate containing inulin and polydextrose has satisfactory physicochemical properties.

Bioactive and sensory quality parameters

Sucrose substitutes used in the food industry should not significantly change the sensory characteristics of a product [61]. However, conventional chocolate is generally preferred to reduced-sugar chocolate as regards textural properties. Overall acceptability depends on mouthfeel, aroma and sweetness.

Continuous phase lipid composition, which influences mouthfeel and melting properties, is important for sensory characteristics. Chocolate triglycerides contain saturated stearic (34%) and palmetic (27%) fatty acids and monounsaturated oleic acid (34%). Chocolates are solid at 20–25°C but melt in the mouth (37°C) [4]. Sensory evaluation depends on ingredient proportions, use of milk crumb instead of milk powder, type of cocoa, blending techniques and processing methods. The type of chocolate and its intended use influence the specifications [43]. The addition of vegetable fats similar to cocoa butter in triglyceride composition and cocoa butter equivalents does not significantly affect texture. Cocoa butter can also be completely replaced with cocoa butter replacers such as lauric fats, palm kernel and coconut oils [39].

Conclusion

Reduced-calorie chocolates are manufactured by replacing cocoa butter and sucralose with polysaccharides, vegetable oils and various sugar substitutes. Our previous research [47] found that guar gum and palm oil are the best substitutes for cocoa butter. Other studies have shown combining replacement fat with bulking agents resulted in better organoleptic properties. Reduced-calorie chocolate has higher viscosity than conventional chocolate. In conclusion, substitution of cocoa butter with vegetable oils combined with bulking agents does not adversely affect the physicochemical and sensory qualities of chocolate. Thus, reduced-calorie chocolate can help decrease fat and sugar consumption compared with conventional chocolates.

Conflicts of Interest

The authors declared they have no conflicts of interest.

REFERENCES

1. Kerr J (2011) Chocolate: a Mesoamerican luxury 1200—1521 – obtaining cacao. http://archive.fieldmuseum.org/Chocolate/history_mesoamerican7.html (accessed 23 Jan 2018)
2. Awad TS, Marangoni A (2006) Ingredient interactions affecting texture and microstructure of confectionery chocolate. In: McPherson A, Gaonkar AG (eds) Ingredient interactions 2. CRC Press, Boca Raton, p 423
3. Afoakwa E, Paterson A, Fowler M (2008) Effects of particle size distribution and composition on rheological properties of dark chocolate. Eur Food Res Technol 226:1259–1268
4. Beckett S (2009) Chocolate manufacture. In: Talbot G (ed) Science and technology of enrobed and filled chocolate confectionary and baked products. CRC Press, Boca Raton, pp 11–28
5. Aidoo RP, Afoakwa EO, Dewettinck K (2015) 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 Sci Technol 62:592–597
6. Glicerina V, Balestra F, Rosa MD, Romani S (2016) Microstructural and rheological characteristics of dark, milk and white chocolate: a comparative study. J Food Eng 169:165–171
7. Jonson BR (2000) Whey protein concentrates in low-fat applications. U.S. Dairy Export Council, Arlington, VA
8. Duflot P (1996) Starches and sugars glucose polymers as sugar/fat substitutes. Trends Food Sci Technol 7:206
9. Harrigan KA, Breene WM (1989) Fat substitutes: sucrose esters and simplesse. Cereal Foods World 34:261–267
10. Boyle A, Long S (2007) Personal nutrition, 6th ed. Thomson/Wadsworth, Belmont, CA
11. Fasina OO, Hallman CHM, Clementsa C (2006) Predicting temperature-dependence viscosity of vegetable oils from fatty acid composition. J Am Oil Chem Soc 83(10):899–903
12. Koushki M, Nahidi M, Cheraghali F (2008) Physico-chemical properties, fatty acid profile and nutrition in palm oil. J Paramed Sci 6(3):4978
13. Norulaini AN, Ahmad A, Fatehah AO, Banana MO, Zaidul ISM, Omar FM (2008) Sterilization and extraction of palm oil from screw pressed palm fruit fiber using supercritical carbon dioxide. Sep Purif Technol 60:272–277
14. Sundram K (2005) Meeting the rising health awareness: the palm oil formula. Palm Oil Developments 43:20–28
15. McIvor ME, Cummings CC, Duyn MA *et al* (1986) Long term effects of guar gum on blood lipids. Atherosclerosis 60:7–13
16. Brown J C, Livesey, G (1994) Energy balance and expenditure while consuming guar gum at various fat intakes and ambient temperatures. Am J Clin Nutr 60(6):956–964
17. Pittler MH (2001) Guar gum for body weight reduction: meta-anal-

ysis of randomized trials. Am J Med 110(9):724–730
18. Chan JLYK (1989) Reduced calorie and reduced fat chocolate confectionery compositions. Patent no. US4810516 A
19. Vuorinen-Markkola H, Sinisalo M, Koivisto VA (1992) Guar gum in insulin-dependent diabetes: effects on glycemic control and serum lipoproteins. Am J Clin Nutr 56(6):1056–1060
20. Haumann BF (1986) Getting the fat out – researchers seek substitutes for full-fat fat. J Am Oil Chem Soc 63:278–286
21. Peters JC, Lawson KD, Middleton SJ, Triebwasser KC (1997) Assessment of the nutritional effects of olestra, a nonabsorbed fat replacement: introduction and overview. J Nutr 127:1539–1546
22. O'Brien CM, Mueller A, Scannell AGM, Arendt EK (2003) Evaluation of the effects of fat replacers on the quality of wheat bread. J Food Eng 56:265–267
23. Plug H, Haring P (1993) The role of ingredient-flavor interactions in the development of fat-free foods. Trends Food Sci Technol 4:150–152
24. Warshaw HS, Powers MA (1999) A search for answers about foods with polyols. Diabetes Educ 25:307–321
25. Wiet SG, Beyts PK (1992) Sensory characteristics of sucralose and other high intensity sweeteners. J Food Sci 57:1014–1019
26. Nishal S (2015) A review on artificial sweeteners. World J Pharmaceut Res 4(6):776–792
27. Wiet SG, Ketelsen SM, Davis TR, Beyts BK (2006) Fat concentration affects sweetness and sensory profiles of sucrose, sucralose, and aspartame. J Food Sci 58(3):599–602
28. Ketelsen SM, Keay CL, Wiet SG (1993) Time-intensity parameters of selected carbohydrate and high potency sweeteners. J Food Sci 58:1418–1421
29. Schiffman SS, Sattely-Miller EA, Graham BG, Bennett JL, Booth BJ, Desai N *et al* (2000) Effect of temperature, pH, and ions on sweet taste. Physiol Behav 68:469–481
30. Jenner MR (1996) The uses and commercial development of sucralose. In: Grenby TH (ed) Advances in sweeteners. Blackie Academic & Professional, Glasgow, pp 253–262
31. Tso P (2003) Gastrointestinal secretion, digestion, and absorption. In: Rhoades R, Tanner G (eds) Medical physiology, 2nd ed. Lippincott Williams & Wilkins, Philadelphia, pp 482–483
32. Goldsmith LA (2000) Acute and subchronic toxicity of sucralose. Food Chem Toxicol 38(Suppl 2):S53–S69
33. FDA (2013) Appendix A: Definitions of nutrient content claims. In: Guidance for industry: a food labeling guide. FDA, Silver Spring, MD, pp 87–90
34. Jeyarani T, Banerjee T, Ravi R, Gopala Krishna AG (2015) Omega-3 fatty acids enriched chocolate spreads using soybean and coconut oils. J Food Sci Technol 52(2):1082–1088
35. Despland C, Gnagi NC, Giacomo V, Neuchatel P (1996) Process for producing an improved sucrose-free milk chocolate. Patent no. US5490996
36. Cully KJ, Carvallo FDL, Abdallah QM, Gaim-Marsoner GR (1997) Method for reducing the viscosity of chocolate. Patent no. US5676995 A
37. Keme T, Bollinger H (1990) Process for the manufacture of sucrose-free, dietetic and/or teeth-sparing chocolate. Patent no. US4980189 A
38. St. John JF, Fetterhoff JG, Carpenter JR, Brown BD, Azzara CD, Tarka Jr. SM *et al* (1995) Reduced fat confectionery products and process. Patent no. US5709903 A
39. Talbot G (1999) Chocolate temper. In: Beckett ST (ed) Industrial chocolate manufacture and use, 3rd edn. Blackwell Science, Oxford, pp 218–230
40. Thompson JL, Drake MA, Lopetcharat K, Yates MD (2004) Preference mapping of commercial chocolate milks. J Food Sci 69(9):406–413
41. Gomes (2007) Bulking and fat replacing agents. In: Varzakas T, Labropoulos A, Anestis S (eds) Sweeteners: nutritional aspects, applications, and production technology. CRC Press, Boca Raton, pp 406–407
42. El-kalyoubi M, Khallaf MF, Abdelrashid A, Mostafa EM (2011) Quality characteristics of chocolate – containing some fat replacer. Ann Agric Sci 56(2):89–96
43. Jackson K (1999) Recipes. In: Beckett ST (ed) Industrial chocolate manufacture and use, 3rd edn. Blackwell Science, Oxford, pp 323–346
44. El-Hadad NNM, Youssef MM, Abd El-Aal MH, Abou Gharbia HH (2011) Utilization of red palm olein in formulating functional chocolate spread. Food Chem 124:285–290
45. Jones SA (1996) Issues in fat replacement. In: Roller S, Jones SA (eds) Handbook of fat replacers. CRC Press, Boca Raton, pp 3–26
46. Prindiville EA, Marshall RT, Heymann H (1999) Effect of milk fat on the sensory properties of chocolate ice cream. J Dairy Sci 82:1425–1432
47. Nazir S, Azad ZRAA (2016) Development of a novel calorie controlled and sugar-free dark chocolate enriched with guar gum. J Indust Res Technol 6(1):1–9
48. Conti A, Pinorini-Godly MT, Colombo ML (2013) Cocoa and chocolate in humans: the rationale for clinical studies on healthy volunteers. In: Watson RR, Preedy VR, Zibadi S (eds) Chocolate in health and nutrition. Springer, New York, pp 525–539
49. Carnésecchi S, Schneider Y, Lazarus SA, Coehlo D, Gossé F, Raul F (2002) Flavanols and procyanidins of cocoa and chocolate inhibit growth and polyamine biosynthesis of human colonic cancer cells. Cancer Lett 175(2):147–155
50. Shively CA, Tarka Jr. SM (1984) Methyxanthine composition and consumption patterns of cocoa and chocolate products. In: Spiller GA (ed) The methylxanthine beverages and foods: chemistry, consumption and health effects. Alan R Liss, New York, pp 149–178
51. Mann R (2015) Natural wellness foods. Lulu Press

52. Eduardo MF, Lannes SCS (2007) Use of texture analysis to determine compaction force of powders. J Food Eng 80:568–572
53. Sokmen A, Gunes G (2006) Influence of some bulk sweeteners on rheological properties of chocolate. LWT - Food Sci Technol 39:1053–1058
54. Joye DD (2003) Shear rate and viscosity corrections for a Casson fluid in cylindrical (Couette) geometries. J Colloid Interface Sci 267:204–210
55. Servais C, Ranc H, Roberts ID (2003) Determination of chocolate viscosity. J Texture Stud 34:467–497
56. Beckett ST (2009) The science of chocolate, 2nd ed. Royal Society of Chemistry, Cambridge, p 240
57. Maheshwari B, Reddy SY (2005) Application of kokum (Garcinia indica) fat as cocoa butter improver in chocolate. J Sci Food Agric 85:135–140
58. Schantz B, Rohm H (2005) Influence of lecithin-PGPR blends on the rheological properties of chocolate. LWT - Food Sci Technol 38:41–45
59. Nebesny E, Dorota Z (2005) Effect of lecithin concentration on properties of sucrose-free chocolate masses sweetened with isomalt. Eur Food Res Technol 220:131–135
60. Abbasi S, Farzanmehr H (2009) Optimization of the formulation of prebiotic milk chocolate based on rheological properties. Food Technol Biotechnol 47:396–403
61. Bolini-Cardello HMA, Da Silva MAPA, Damasio MH (1999) Measurement of the relative sweetness of stevia extract, aspartame and cyclamate/saccharin blend as compared to sucrose at different concentrations. Plant Foods Human Nutr 54:119–130