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Review on Effects of Baking with Fat, Fat Polymorphism and Commonly Used Fat Replacers.

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Abstract

Fats are used widely in food industry for preparation of many products. Bakery items such as cake and bread are highly dependent on fat to obtain the required tenderness and other textural properties fat imparts. Fat crystallization is an important phenomenon that takes part at molecular level. It contributes to physical and chemical properties of fat that affect the end products. Fat replacers are used in many food products as it reduces adverse effects caused due to obesity and diabetes. Currently, they are made out of lipid, protein and carbohydrates. Most of the fat replacers work as substitutes for raw materials and even reduce complications that occur in production processes. Lipid based fat replacers are mostly produced from modifications to the triglycerides. Protein-based ones are derived from protein rich natural food such as eggs and milk. Most of the carbohydrate-based fat mimetics are made from cereal.

1. Introduction

Fats and oils are important ingredients in a variety of foods. They contribute to tenderness in shortened cake, and by aerating batter, fats aid in establishing texture in cakes. Fat contributes to flavor, or the combined perception of mouthfeel, taste, and aroma/odor. It increases the feeling of satiety during meals and influences the order in which components of flavor are released when foods are eaten [1]. Fats have a lubricating effect and produce a sensation of moistness in the mouth. They are a medium for transferring heat to foods.

Fat has major roles in baking, including shortening, creaming, giving flavor and making an emulsion with the other ingredients. How well it will perform each of these functions depends largely on the "slip point", which is the temperature at which the fat just begins to melt. Like sugar, fat interferes with gluten development, weakening the cake structure. Fat 'shortens' a dough by weakening its gluten network, resulting in the baked product being softer, breaking easily and having a more tender mouthfeel. Fat can trap air during beating and mixing, producing a batter that consists of masses of tiny air bubbles trapped within droplets of fat [2].

Plastic fats aid in incorporating and retaining air in the form of small bubbles, distributed throughout the batter. These bubbles serve as gas cell nuclei into which carbon dioxide and steam diffuse during baking. Thus, the smaller the air cells, the larger the volume and finer the grain in the final cake. The larger and fewer the air cells, the lower the volume and coarser the grain. Fineness and uniformity of grain is enhanced with fats of good creaming quality, rather than soft or

liquid fats, unless methods of mixing are altered [3]. Usually the fats used should have a bland flavour to prevent them from changing the flavour of the finished product, but occasionally fats are chosen on the basis of their flavour. According to Czernohorsky et al. (2000), the fat chosen needs to be able to form an emulsion with the other ingredients in the batter or dough.

As stated in Ognean et al. (2006), From a physiological standpoint, fat is a source of fat soluble vitamins, essential fatty acids, precursors for prostaglandins, and is a carrier for lipophilic drugs. Fat is the most concentrated source of energy in the diet, providing 9 kcal/g compared to 4 kcal/g for proteins and carbohydrates.

2. Forms of fat

Shortening is 100 percent fat and is solid at room temperature. It is often made of hydrogenated (solidified by adding hydrogen) vegetable oils, but sometimes contains animal fats. There are emulsifiers in shortening to help emulsify shortening and liquid. This means that oil and water stay mixed together, creating an even distribution of flavors and a consistent texture in batters and dough [4]. Shortening works best for some types of baking because it contains no water. Water mix with flour and form gluten that toughens a product. As it has no water, shortening produces tender, flaky products [5].

Butter is made from cream and has a fat content of at least 80 percent. The remaining 20 percent is water with some milk solids. According to Lauterbach and Albrecht (1994), butter possess the ability to impart a good flavor without a greasy mouthfeel to baked goods because it melts at body temperature. As for a research finding, cake made with butter has the highest tenderness and velvetiness than the ones made with margarine [6]. Margarine is made from fat or oil that is partially hydrogenated, water, milk solids, and salt. Vitamins and coloring are usually added manufacturing processes as well.

The fat or oil can be of animal or vegetable origin. Margarine has the same ratio of fat to non-fat ingredients as butter (80:20) and can be used interchangeably with butter. According to a research done by Matthews and Elsie (1966), cakes made with margarine have highest evenness in grains than that of butter. Reduced fat substitutes have less than 80 percent fat. These do not work the same as butter or margarine in baked goods. Fat free margarines also are available and contain no fat. As Lauterbach and Albrecht (1994) mentioned, these margarines are best used as spreads.

Oil is used in some muffin, bread and cake recipes. Oil pastry is mealy rather than flaky. If oil is used in place of a solid fat for some cake recipes, the texture will be heavier unless the sugar and egg are increased. As for the report of International Food Information Council (2016), Vegetable oil (with the exception of olive oil) yields the best results in many box cake mixes.

3. Fat Polymorphism

Polymorphism of fat crystals is an important phenomenon which relates the molecular structures of fats to their macroscopic physical properties. This is because melting and solidification behavior, morphology, and aggregation of fat crystals in bulk and emulsions states are determined by the polymorphic modifications of the fats [7]. The three fundamental polymorphs are called alpha (α), beta (β) and beta-prime (β') [8]. The nature and compositions of three fatty acid moieties of a TAG molecule, defined R1, R2, and R3 plays an important role in polymorphism.

The three polymorphs are based on its subcell structures, which define cross-sectional packing modes of the zigzag aliphatic chain. As mentioned by Widlak et al. (2001), the α form has been revealed in chilled milk fats in the oil-in-water (O/W) emulsion state like ice cream. According to Sato and Ueno (2005), The structure and texture of ice cream is caused by a network of partially coalesced α-form crystals and ice crystals that surround air bubbles to form discontinuous foams. Cocoa butter crystals in the confections are in the β modification. Tempering is required for β form, which is used for chocolate, cocoa butter, and cocoa butter equivalents. Cocoa butter replacers (CBR) and cocoa butter substitutes (CBS) can crystallize without tempering into their stable β' polymorph upon simple cooling.

The small needle-like β' crystals impart good plasticity that is desirable in products such as margarine, shortening, and baking fats. So β' is the most suitable for cake shortening as per Sato and Ueno (2005). But in cake shortening, the fat system, typically composed of fully hydrogenated or partially hydrogenated fat, undergoes a crystalline phase change from beta-prime (β') to beta (β) crystals under widely fluctuating temperature conditions. This reduces cake baking performances. This happens because the large plates of solid fat, associated with beta crystals, are much less effective in entrapping dispersed air. In cakes, plastic shortenings in the beta-prime phase are more desirable over shortenings which are in the stable beta phase [9].

4. Powdered Fat

There are two types of powdered shortenings produced currently. They are spray-dried fat emulsions with a carrier and spray-chilled or beaded hard-fat blends [10]. The spray-dried powdered shortenings are partially hydrogenated shortenings encapsulated in a water-soluble material. Also according to O'Brien (2009), shortenings can be homogenized in solution with a variety of carriers (e.g., skim milk, corn syrup solids, sodium caseinate, soy isolate). They are currently used in prepared mixes like cake mixes. Emulsifiers may be included with the shortening for finished product functionality [11]. According to a research conducted by M. L. Vignolles et al. (2009), emulsion droplet size and droplet aggregation depends on the homogenizing pressures and are also affected by spray atomization [12].

As mentioned by O'Brien (2009), aggregation is usually greater after spray atomization, resulting in greater viscosities. In spray dried fat powder, fat contents usually range from 50 to 80%, depending on the original emulsion composition before spray drying. Hard-fats can be powdered or beaded without the aid of a carrier. Three principal methods of forming powder or beaded fats are practiced in the United States. They are spray chilling, grinding flaked product and spray flaking and grinding. Beaded products produced by grinding flakes or spray flaking for immediate grinding have granular shapes that can be metered at uniform rates with vibratory or screw feeders and resist stratification or separation in mixes with other granular materials.

5. Fat Replacers

The three main categories of fat replacers which are lipid, protein, or carbohydrate-based fat substitutes [13]. According to Ognean et al. (2006), Fat replacers are generally categorized into two major groups: fat substitutes and fat mimetics. Fat substitutes are ingredients that have a chemical structure somewhat close to fats and have similar physiochemical properties. These are generally referred as lipid-based substitutes and also known as true fat substitutes. A true fat substitute is a substance that physically and chemically resembles triglycerides and can theoretically replace the fat in foods on a one-to-one, gram-for-gram basis [14]. According to Archilla (1999), They are usually either indigestible or contribute lower calories on a per gram basis.

Fat mimetics, on the other hand, are ingredients that have distinctly different chemical structures from fat. They have diverse functional properties that mimic some of the characteristic physiochemical attributes and desirable eating qualities of fat including viscosity, mouthfeel and appearance. As mentioned by Akoh (1998), They can imitate the organoleptic or physical properties of triglycerides but cannot usually replace fat on a 1:1 basis. Fat mimetics are commonly called protein- or carbohydrate-based substitutes.

Long term studies have not conducted upon the fat replacers and their impact on human health. However, fat replacers could positively impact overall diet quality if the person uses these foods as part of a total diet plan that promotes choosing fats wisely and balancing total energy intake. Peterson and Sigman-Grant (1997) observed that fat-modified products assisted children to reach dietary recommendations for total energy and total fat intake [15]. This can adversely affect the vitamin E intake of the overall food. Furthermore, several short-term studies in adults indicate that fiber used as a fat replacer may be important for regulating food intake, preventing weight gain, and helping with weight maintenance [16][17]. This has also made some positive outcome upon diabetic patients as well.

5.1 Lipid-Based Fat Substitutes

There are two categories in lipid-based fat substitutes. The first is triglycerides that have been modified and are partially absorbed. The second is synthesized to have structures similar to triglycerides and are no longer metabolized in the body. According to the Institute of Food Technologists (2016), Sucrose fatty acid polyesters are mixtures of sucrose esters formed by chemical transesterification or interesterification of sucrose with six to eight fatty acids. Transesterification is the exchange of an acyl group or radicals between an ester and an acid, alcohol, or an amine.

Interesterification is the exchange of an acyl group or radicals between two esters. Institute of Food Technologists (2016) have mentioned, the sucrose polyester commonly known as olestra is manufactured from saturated and unsaturated fatty acids of chain length C12 and higher, obtained from conventional edible fats and vegetable oils. Olestra is non-caloric because the large size and number of the fatty acids are not metabolized.

Since Olestra passes unmetabolized through the gastrointestinal tract, it has the potential to cause abdominal cramping, stool softening, and reduce the absorption of fat-soluble vitamins and nutrients according to Akoh (1998). Olestra was approved by the FDA in 1996 for use in baked and snack goods because it can withstand high-heat applications.

Emulsifiers are used as fat extenders. Emulsifiers have hydrophilic and lipophilic properties that allow them to keep immiscible liquids suspended [18]. Even though, emulsifiers contain the same calories as fat, 25-78% less is needed to produce fatlike characteristics. Common emulsifiers are lecithin, mono- and diglycerides, olyglyceril esters, olysorbates, and sodium stearoyl lactylate. Emulsifiers contain both hydrophilic and lipophilic properties that enable it to stabilize the interface between fat and water droplets through hydrogen bonding.

By acting as surface active molecules, emulsifiers can replace up to 50% of the fat in a formulation [19]. They also provide and stabilize aeration, provide lubricity, complex with starch, interact with protein, modify the crystallization characteristics of other fats, promote and stabilize foam, control syneresis, carry flavors, and control rheology. Emulsifiers are most effective in replacing the functionality of fat when used in combination with other ingredients. Emulsifiers are useful in margarines, baked goods, frozen desserts, dairy products, spreads and shortenings, processed meats, whipped toppings, cake frostings and fillings, and confections.

5.2 Protein-Based Fat Mimetics

Protein-based fat substitutes are derived from protein sources such as milk, egg, whey, or vegetable proteins. According to Akoh (1998), some protein-based fat substitutes undergo microparticulation (sheared under heat), which produces microscopic round particles similar to fat particles that mimic the mouthfeel and texture of fat. Some fat mimetics are processed to modify other aspects of ingredient functionality, such as water binding and emulsification properties. Although the substances are generally not sufficiently heat stable to withstand frying, they are suitable for use as ingredients in foods that may undergo cooking or baking according to Calorie Control Council (1996). Simplesseâ is a microparticulated protein-based fat mimetic. Simplesseâ cannot be used in high-temperature food applications, which could easily denature the proteins. On a dry basis Simplesseâ provides 4 kcal/g, whereas a hydrated gel provides 1 kcal/g.

5.3 Carbohydrate-Based Fat Mimetics

For several years, carbohydrate-based fat substitutes have been used to partially or fully replace fat. These mimetics are derived from cereals, grains, and plants that include digestible and nondigestible carbohydrates. Digestible carbohydrates provide 4 kcal/g, while nondigestible carbohydrates provide negligible calories. Examples of carbohydrate-based fat substitutes include polydextrose, pectin, cellulose, gums, and starch derivatives (modified starches, dextrins). Carbohydrate-based fat-substitutes provide some of the functions of fat by binding water, and providing texture, mouthfeel, and opacity.

Polydextrose is a bulking agent made by the random polymerization of glucose, sorbitol and citric acid. Because human digestive enzymes cannot totally break down polydextrose, some of it passes through the body unabsorbed. Consequently, it contributes only one calorie per gram [20]. Polydextrose is often added to nonnutritive sweeteners to maintain texture, body and mouthfeel in low-calorie products. It is also used as a humectant to replace fat or sugar in baked goods, chewing gum, salad dressings, etc..

A study conducted to understand effect of fat mimetics on physical, textural and sensory properties of cookies have indicated, improved polydextrose, a combination of polydextrose with maltodextrins or a combination of polydextrose with microparticulated whey proteins are the most suitable fat replacers for soft-type cookies. Also these mimetics can replace upto 35% of fat in cookies [21].

Reference

(i) Ognean,C. F., Darie, N. & Ognean, M. (2006). Review-Natural Food Extracts and Additives, Journal of Agroalimentary Processes and Technologies, University of Sibiu, Faculty of Agricultural Sciences, Food Industry and Environmental Protection, Volume XII, No. 2, 433-442

(ii) Czernohorsky, J. H., & Hooker, R. (2008) The Chemistry of Baking, New Zealand Institute of Chemistry. NZIC, Web, http://nzic.org.nz/chemprocesses/food/6d.pdf, (Accessed 10, November, 2016)

(iii) Bennion, M. (1995). Introductory Foods, 10th ed., Prentice-Hall, Inc. Upper Saddle River, NJ, 183-213

(iv) Lauterbach,S. & Albrecht, J. A. (1994) Functions of Baking Ingredients, Published by corporative extension, Institute of agriculture and natural resources, University of Nebraska Lincoln, web, http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1412&context =extensionhist, (Accessed 10, November, 2016)

(v) Anonymous, (2016). Everything you need to know about the functions of fats in food, International Food Information Council, 1-5

(vi) Matthews, R. H. & Dawson E. H. (1966). Performance of fats in white cake, Cereal Chem, Vol:43, 538-545

(vii) Widlak, N., Hartel, R. & Narine, S. (2001) Crystallization and solidification properties of lipids, molecular aspects in fat polymorphism, Chapter 1, 1-35

(viii) Sato, K. & Ueno S. (2005). Polymorphism in Fats and Oils, Bailey's Industrial Oil and Fat Products, Sixth Edition, Six Volume Set. Copyright, John Wiley & Sons, Inc. 77-116

(ix) Ghotra, B. S., Dyal, S. D. & Narine, S. S. (2002). Lipid shortenings, Review, Agri-Food Materials Science Centre, University of Alberta, Food Research International 35 (2002) 1015–1048

(x) O'Brien, R. (2009). Fats and Oils Formulating and Processing for Applications. CRC Press.

(xi) Mezzenga, R. & Stephane Ulrich, S. (2010). Spray-Dried Oil Powder with Ultrahigh Oil Content, Abs, American Chemical Society, Nestlé Research Center, Vers-Chez-les-Blanc, 1000 Lausanne 26, Switzerland

(xii) Vignolles, M.L., Lopez. C., Madec, M. N., Ehrhardt, J. J., Méjean, S., Schuck, P., Jeantet, R. J. (2009). Fat properties during homogenization, spray-drying, and storage affect the physical properties of dairy powders, Dairy Sci. 92(1), 58-70

(xiii) Archilla, L. L. (1999). Evaluation of maltodextrin gel as a partial replacement for fat in high –ratio white-layer cake formulation, B. Sc., in Human Nutrition, Foods, and Exercise, Thesis, Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia

(xiv) Akoh, C.C. (1998). Fat replacers, The institute of food technologists' expert panel on food safety and nutrition, Food Technology, 52(3): 47-53

(xv) Peterson, S. and Sigman-Grant, M. (1997). Impact of adopting lower-fat food choices on nutrient intake of American children. Pediatrics.; 100: E4

(xvi) Archer, B.J., Johnson, S.K., Devereux, H.M., and Baxter, A.L. (2004). Effects of fat replacement by inulin or lupin-kernel fiber on sausage patty acceptability, post-meal perceptions of satiety and food intake in men. Br J Nutr.; 91: 591–599

(xvii) Reyna, N.Y., Cano, C., Bermudez, V.J., Medina, M.T., Souki, A.J., Ambard, M., Nunez, M., Ferrer, M.A., and Inglett, G.E. (2003). Sweeteners and β-glucans improve metabolic and anthropometrics variables in well-controlled type 2 diabetic patients. Am J Ther.; 10: 438–443

(xviii) Gershoff, S.N. (1995). Nutrition evaluation of dietary fat substitutes, Nutrition Reviews, 53(11): 305-13

(xix) Anonymous, (2016). Fat Replacers, Calorie Control Council, web, http://caloriecontrol.org/fat-replacers/ (Accessed 15, November, 2016)

(xx) Napier, K. & Kava, R. (1997). The cutting edge of cutting calories, the American Council on Science and Health October, web, http://www.acsh.org/wpcontent/uploads/2012/04/2004 0402_Fat_Replacers1997.pdf (Accessed 11, November, 2016)

(xxi) Zoulias, E., Oreopoulou, V., & Tzia, C. (2000). Effect of fat mimetics on physical, textural and sensory properties of cookies. International Journal Of Food Properties, 3(3), 385-397. doi: 10.1080/10942910009524643