The Contributions of Food Science to Help Americans Achieve the Dietary Guidelines - Future Opportunities and Challenges

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feeding the minds that feed the world

Institute of Food Technologists (IFT)

- Founded in 1939
- Dedicated to working together to advance the science of food, with the ultimate goal of ensuring a safe, nutritious, affordable and abundant food supply
- Non-profit scientific society—over 18,000 members from more than 100 countries
- Brings together food scientists, technologists and related professionals from academia, government and industry

Outline

- Role of food science and technology
- Functions, opportunities and challenges
  - Sodium
  - Sugars
  - Fats and fatty acids
- Unintended consequences
- Nutrient contributions from packaged foods
- Summary
- Q&A

Food science and technology

- Food processing evolved from the need to preserve food, to improve nutritional and other desirable qualities, and for better consumer health and wellness.
- Food scientists and technologists transform raw food materials and ingredients into a variety of safe, nutritive, palatable, and affordable foods that may be consumed year around.
- Current farm-to-fork food system is complex and includes:
  - Agricultural production and harvesting
  - Post-harvest processing including holding and storing of raw materials
  - Ingredient transformation
  - Food manufacturing (formulation, food processing and packaging)
  - Transportation and distribution
  - Retailing; food service; and food preparation at home

Food science and technology (cont.)

In addition to meeting consumer needs for palatable, safe, affordable, nutritious, convenient, and diverse foods, food science and technology serves many other purposes including:

- Improve health and wellness
- Enhance nutritional quality of food
- Provide an efficient nutrient delivery system
- Improve digestibility, bioavailability, and palatability of foods
- Improve food safety and quality (remove potential toxic substances and anti-nutrients, prevent growth of pathogens, control spoilage microorganisms)
- Develop technologies/processes to produce foods more sustainably
- Reduce post-harvest losses
- Increase shelf-life of foods
- Improve transportability of foods

Sodium

- Sodium is an essential nutrient – regulates extracellular volume, maintains acid-base balance, neural transmission, renal function, cardiac output, and myocytic contraction
- Occurs naturally in foods such as milk, beets and celery
- Most common form of sodium in food is sodium chloride – primary source of sodium in diet
- Sodium and salt often used interchangeably
- For thousands of years salting was the primary method of preserving foods -- meat, fish, eggs, and vegetables
- By 19th century other methods such as canning, refrigerating and freezing decreased the need to use salt
- Now commercial methods such as pasteurization, irradiation and other methods have decreased the use of salt in foods
- Adding iodine to salt has eliminated iodine deficiency in the U.S.

Sodium: Functional role in foods

- Nutrition
- Microbiological safety
- Palatability
- Flavor—improves sensory properties of foods, flavor enhancer, masks bitter flavors
- Texture
- Structure integrity
- Preservation

Common sodium-containing compounds and their functions in food

Neutralizing Agents:
Trisodium phosphate
Sodium sesquicarbonate
Sodium phosphate
Sodium DL-malate
Sodium dihydrogen phosphate
Sodium dihydrogen citrate
Sodium citrate
Sodium adipate
Aluminum sodium sulfate
Sodium potassium tartrate
Sodium acetate

Flavor-Enhancing Agents:
Monosodium glutamate
Disodium 5′-guanylate
Disodium 5′-inosinate
Disodium 5′-ribonucleotides

Emulsifying Agents:
Sodium pyrophosphate
Dioctyl sodium sulfosuccinate
Disodium hydrogen phosphate
Sodium alginate
Sodium caseinate
Sodium phosphate
Trisodium citrate
Trisodium phosphate
Sodium stearoyl lactylate

Buffering Agents:
Aluminum sodium sulfate
Disodium hydrogen phosphate
Sodium adipate
Sodium dihydrogen citrate
Sodium dihydrogen phosphate
Sodium DL-malate
Sodium hydrogen carbonate
Sodium phosphate
Trisodium citrate
Trisodium phosphate

Leavening Agents:
Sodium bicarbonate
Disodium pyrophosphate
Sodium acid pyrophosphate
Sodium aluminum phosphate
Sodium hydrogen carbonate

Thickening Agents:
Sodium alginate
Sodium carboxymethylcellulose

Anticaking Agents:
Sodium aluminosilicate
Sodium ferrocyanide

Bleaching Agent:
Sodium metabisulfite

Stabilizing Agents:
Disodium ethylenediaminetetraacetic acid (EDTA)
Disodium pyrophosphate
Potassium sodium L-tartrate
Sodium alginate
Sodium carboxymethylcellulose
Sodium caseinate
Trisodium citrate
Sodium stearoyl lactylate

Texture-Modifying Agents:
Sorbitol sodium
Sodium tripolyphosphate
Pentasodium triphosphate
Disodium hydrogen phosphate

Dough-Conditioning Agents:
Sodium stearoyl lactylate
Sodium stearyl fumarate

Moisture-Retaining Agents:
Sodium hydrogen DL-malate
Sodium lactate
Sodium lauryl sulfate

IOM Report, 2010

Sources of sodium in the diet

- NHANES data - 2007-2008 (CDC, 2012)
  - Age 2+years
  - Top ten food categories - 44% of the overall sodium consumption
    - Bread and rolls
    - Cold cuts/cured meats
    - Pizza
    - Poultry
    - Soups
    - Sandwiches
    - Cheese
    - Pasta mixed dishes
    - Meat mixed dishes
    - Savory snacks

Sodium reduction strategies: Opportunities

Goal is to develop palatable, nutritious, safe, and affordable low-sodium foods

- Small stepwise reductions (5-10%) of sodium chloride over time in foods will help decrease sodium intake without being noticeable
- Salt substitutes/enhancers
  - Potassium chloride, calcium chloride, magnesium sulfate, yeast extracts, hydrolyzed vegetable protein, MSG, lactates, sea salts, for example
  - Use of herbs and spices
- Umami-tasting extracts from aqueous plants
- Salts with altered crystal structure – larger surface area
  - Created by manipulating drying process
  - Greater salty taste with smaller amounts
  - Useful where salt is used on the surface of the foods
- Increase solubility of salt crystals to increase the sensation of saltiness for a given amount of salt
- Salt microspheres—hollow crystals with large surface area and high solubility
- Increase potassium content in foods to balance the sodium
- Reduced portion sizes/packages and other ways to reduce calorie consumption
  - High correlation between calorie and sodium consumption

Sodium reduction strategies: Challenges

- Food processing and safety challenges:
  - Palatability is the biggest barrier
    - Lithium chloride provides similar saltiness but it is toxic
    - Salt replacers and substitutes provide after taste (such as bitter, metallic and astringent tastes)
    - Potassium chloride can replace up to 30% of sodium chloride in many foods, but beyond that the food is usually unpalatable
    - Other ingredients may be added to mask the off flavors
  - Microbiological instability
  - Salt replacers/substitutes may have limited applications
  - Sodium replacers/substitutes may provide the salty taste but cannot compensate for the other functions of sodium such as texture of dough, microbiological safety and shelf life
  - Increase cost—salt replacers, bitter blockers, flavor enhancers, new technologies
  - Rejection by consumers of foods with large reductions in sodium is due to palatability; especially when other products are available with more acceptable (more salty) taste

Efforts to reduce sodium

- In recent years, food manufacturers have responded to the calls for reduced sodium intake by launching a number of no-, very low-, low-, and reduced-sodium foods across many food product categories
- As part of the National Salt Reduction Initiative, reformulation efforts have led to reduced sodium content in foods
  - 21 companies reduced sodium content in popular foods such as breakfast cereals, canned soups, cheese, pasta sauce, and tomato sauce
  - Sodium levels in ready-to-eat breakfast cereals decreased by 11.2%, for example (Thomas et al., 2013)

Efforts to reduce sodium (cont.)

- According to the Mintel's Global New Products Database
  - Low-, no-, or reduced-sodium claims increased almost 115% from 2005 to 2008 due to public health initiatives to educate consumers about the potential risks of high sodium intake
  - Most recent research shows that the number of these claims has decreased 5% during 2010–2011
  - The decline is perhaps due to poor sales and challenges in finding suitable salt replacers
    - Early on, food manufacturers made public statements about their sodium reduction efforts
    - Some manufacturers have begun to take a "stealth health approach" by reducing sodium in foods without marketing them to consumers as being lower in sodium, because consumers often perceive these claims as a sacrifice to flavor

Sugars: Intrinsic and added

- Sugars occur intrinsically in foods, e.g., fructose, glucose and sucrose in fruits, lactose in dairy products.
- Types of sugars added in foods:
  - Agave nectar, brown sugar, corn sweetener, corn syrup, dextrose, evaporated cane juice, fructose, fruit juice concentrates, glucose, high-fructose corn syrup (HFCS), honey, invert sugar, lactose, maltose, malt syrup, maple syrup, molasses, raw sugar, sucrose, sugar, and syrup

Sugars: Intrinsic and added (cont.)

- Functional properties depend on the composition of the intact sweetener (mono- or disaccharide) in the food or beverage
- Metabolic properties depend on the proportion of monosaccharides (free fructose and glucose) reaching the bloodstream after digestion
- Sugars are similar in terms of:
  - Composition
  - Fructose-to-glucose ratio
  - Sweetness
  - Absorption, and metabolism
  - Reformulation by substituting one sugar for another may not significantly change the nutritional value

Sweeteners: Caloric vs. non caloric

Types of sweeteners

- Caloric sweeteners
  - Caloric sweeteners – provide energy
    - Sugars: 4 kcal/g
    - Polyols: 0.2 – 2.6 kcal/g
- High-intensity sweeteners
  - No or negligible calories due to high sweetness intensity
    - Amino acid based: 4 kcal/g
    - Non digestible, non-caloric high intensity sweeteners: 0 kcal/g (e.g., acesulfame K, saccharin, sucralose, stevia)

Sugars: Attributes in food

- **Nutritional value**
- **Sensory:** sweetness, taste, aroma, texture, appearance
- **Physical:** crystallization, viscosity, grain size and distribution, hygroscopicity, osmotic pressure
- **Microbial:** preservation, fermentation
- **Chemical:** inversion, carmelization

Davis E. 1995. Functionality of sugars: Physicochemical interactions in foods. J Am Clin Nutr 62:170S-7S.

Sugars: Functional role in foods

- Sugars are used in foods for many functions beyond sweetness:
  - Balance tartness (beverages), flavor enhancement, improve mouthfeel
  - Safety through available water control
  - Preservation (e.g., frozen fruits)
  - Freezing-point balance in ice cream
  - Moisture management in textured food products
  - Fermentation, browning, and volume and structure in baked goods and cereals
  - Sucrose used in candies for properties such as recrystallization
  - Sucrose used in dry mixes for dispersibility – need crystallized sugar
  - HFCS provides acid stability in food and beverage products over time

Sources of added sugars in the diet

NHANES 2007-2008; ages 2+ years (Welsh et al., 2011)

- **Sweets – 47.8 g** (sodas, candies and gums, added sugars and syrups, fruit-flavored drinks (fruitades) and sports drinks, presweetened coffees and teas, alcohol-containing drinks, and energy drinks)
- **Grains – 17 g** (cakes and cookies, ready-to-eat cereals, breads and muffins, and other grains)
- **Dairy – 7.9 g** (dairy desserts, milk, yogurt, and other dairy)
- **Protein sources - 1.8 g** (combination of meat, eggs, beans)
- **Fruit and vegetables – 1.7 g**
- **Fats and oils – 0.6 g**

Sugar reduction strategies: Opportunities

- Sugar substitutes:
  - Expand food choices
  - Control carbohydrate and caloric intake
  - Help manage weight
  - Help in controlling blood sugar in individuals with diabetes
  - Reduce the potential for dental caries

- Sugar substitutes include:
  - Intense sweeteners (e.g., aspartame, saccharin, sucralose, stevia, monk fruit)
  - Polyols or sugar alcohols(e.g., erythritol, polyglycitols, isomalt, lactitol, maltitol, sorbitol, xylitol, mannitol)
  - Fructosaccharides or oligofructans, fructose polymers
  - Sugar substitute blends (e.g., sugar alcohol and stevia)

Sugar reduction strategies: Challenges

- Consumer acceptability
  - Lowering added sugars gradually over time to moderate consumers' palates to find "less sweet" acceptable
- Safety consideration and shelf life
- Nutritional impact
- Intense sweeteners: lack bulk, loss of granulation and texture in foods, loss of viscosity and mouthfeel in beverages
- Polyols lack crystallization ability, and have laxative effects in high concentrations
- Depending upon the sugar substitute used, complete redesign, not a simple reformulation is needed
- Concerns about long ingredient list due to addition of bulking agents, sweetness enhancers and other ingredients used to replace sugars
- Availability, cost and practical application of using sugar substitute in foods and beverages

Efforts to reduce sugars

NHANES (Welsh et al., 2011):

- The absolute intake of added sugars in people 2 years and older has recently decreased by 24% over a period of 8 years

  100.1 g/d (95% CI: 92.8, 107.3 g/d) in 1999–2000

  76.7 g/d (95% CI: 71.6, 81.9 g/d) in 2007–2008

- Reduction in sugar-sweetened soda a significant factor
- Food scientists have reformulated foods with reduced sugar content including breakfast cereals, soft drinks, dairy foods, and bakery foods, e.g., sugar content in ready-to-eat breakfast cereals has been decreased by 7.6% (Thomas et al., 2013)

Fats and fatty acids

- Dietary fats:
  - Source of energy and essential fatty acids
  - Aid in absorption and metabolism of fat soluble vitamins
  - Act as carrier for nutrients
  - Contribute to satiety

Fats and fatty acids: Dietary guidance

- Fats have a long evolving history:

  Food scientists, technologists and the food industry have responded to the evolution of the dietary guidance on fats

  - Shift from animal fat to tropical fats to reduce cholesterol intake

    - Recommendation to use margarine instead of butter, reduce lard
  - Development of low-/no-fat products to reduce total fat consumption
  - Recommendation to reduce saturated fat — leading to the use of partially hydrogenated oils
  - Shift from tropical fats to oils high in PUFA and now to MUFA and oils high in oleic acid
  - Replacing partially hydrogenated oils to reduce/eliminate trans fat

Fats and fatty acids: Functional role in foods

- Fats are used in foods for several purposes including:
  - Development of flavor, color, texture, and stability
- Fats are chosen based on the ability to confer textural variety in sauces and dressings, chocolates and confectionaries, and baked goods
- The chemistry of fats and oils contributes to distinct functional role of fats and oils in food formulation
- And it is the same chemistry that is believed to affect the nutritional and health outcomes

Fats and fatty acids: Opportunities

- In recent years, advances in food science, technology and agriculture have been underway to address the nutritional and genetic makeup of alternative oil sources such as sunflower, canola, and soybean.
- By altering the production technology, new oils have the potential to address current health concerns.
- Fatty acid compositions have been modified via either traditional selective hybridization or gene insertion techniques or innovative technologies
  - To improve nutritional profile
    - Low in saturated fatty acids
    - Low in polyunsaturated fatty acids
    - High in monounsaturated fatty acids (e.g., oleic acid)
    - High in omega-3 fatty acids
  - To improve flavor stability to preclude the need for partial hydrogenation
  - To improve heat and oxidative stability
  - To improve storage and shelf life
- Recent innovations include:
  - Oleic acid (e.g., soybean, canola, sunflower)
  - Oleic and stearic acids (e.g., sunflower)
  - Omega-9 acids (e.g., canola, sunflower)
  - EPA and DHA (e.g., canola)
  - Omega-3 stearidonic acid (e.g., soybean)
  - Algal flour

Innovations in fats and oils (cont.)

- Enzymatic interesterification helps design the oil to provide desirable melting profile and other functions
  - Eliminate or reduce trans fat
- Blending of different oils or fat fractions to increase functionality
- Techniques to develop functional shortenings by blending cellulose fibers and triglycerides
  - Reduce saturated fatty acid levels by more than 40%
  - Increase monounsaturated fatty acids
  - Virtually trans fat free

Innovations in fats and oils (cont.)

- Genetically enhanced soybean oil:
  - High in oleic acid (75%)
  - Contains less than 3% linolenic acid (for improved flavor and stability)
  - 20% less saturated fat than regular soybean oil
  - No trans fat
  - Heat stability for frying and longer fry life
  - Provides flexibility in food preparation and mixing with other oils
  - Suitable for both extreme high and low temperature
  - Volume expected to increase from 300 million lbs in 2014 to 750 million lbs in 2015 and 9 billion lbs by 2023

Innovations in fats and oils (cont.)

- High oleic acid canola oil
  - High oxidative stability
  - Low levels of saturated fats
  - Trans fat free
  - Bland flavor
  - Extended storage and shelf life

- High oleic acid sunflower oil, canola oil and soybean oil have been in the market in the last 5 years (United Soybean Board. Personal communication. March 5, 2014)
- Efforts are underway to create High Stearic High Oleic acid oils

Innovations in fats and oils (cont.)

- Soybean oil is widely used in foods for human consumption
- High oleic soybean oil is expected to increase to 35-40% of the domestic crush by 2023
- Flaxseed oil and flaxseed are sold for human consumption in specialty stores
- Work is being done to develop high oleic safflower and high oleic peanut oil
  - Both are low volume commodity oils, therefore their oleic counterpart may be smaller in volume

United Soybean Board. Personal communication. March 5, 2014

Innovations in fats and oils (cont.)

Omega-9 oils

Since 2006, use of omega-9 oils has resulted in removal of 700 million pounds of trans fat and 300 million pounds of saturated fat from the North American diet.

- Canola omega-9 oil:
  - High in mono- and polyunsaturated fats
  - Low in saturated and trans fat
- Sunflower omega-9 oil:
  - No saturated fats
  - Zero trans fat
  - High in monounsaturated fatty acids

Innovations in fats and oils (cont.)

- Omega-3 canola oil
  - Rich in EPA and DHA
  - Shelf stable
  - Expected to be available in the market by 2020

- Omega-3 stearidonic acid (SDA) oils
  - About 30% of SDA converts to EPA — a rate up to five times that of alpha-linolenic acid

- In the next 10 years, this may increase the sustainability quotient of these critical fatty acids and allow for inclusion in more foods
- However, addition of these sensitive fats may alter the stability of foods and have the unintended consequence of altering the bioavailability of micronutrients that depend on fat for absorption
- The implications are not fully known

Dr. Mario Ferruzzi. Personal Communication, February 25, 2014.

Innovations in fats and oils (cont.)

- Algal flour:
  - Derived from algae
  - Contains more than 50% lipids (primarily monounsaturated fatty acids), 1/3 carbohydrates (polysaccharides, dietary fiber, and simple sugar)
  - Also contains protein, phospholipids, mono- and diglycerides, potassium, carotenoids and B-vitamins
  - Improved product stability and consistency
  - Can be used for fat-or calorie-reduced foods

Fats and fatty acids: Challenges

- “Healthier ”oils are almost always intrinsically less stable due to the unsaturated fatty acid content
  - Heat stability for cooking
  - Ambient temperature stability over weeks/months
- Requirement for solid fat to provide functionality and structure cannot be eliminated, e.g., cookies
- Taste challenges remain to be solved with many of the newer oils, compounded by the lower oxidative stability
- Current cost of some new fats inhibits use in many products, e.g., interesterified fats
- Complexity, time and cost of fat replacement is frequently the highest of any product reformulation

Efforts to reduce trans fat

- Food companies have responded to the dietary guidance and consumers' concerns, while also delivering on consumers’ quality and taste expectations
  - Creating new fats/oils or blends to reformulate foods to reduce both saturated fat and trans fat
    - Voluntarily lowered the amounts of trans fats in food products by over 73%, since 2003
    - To reformulate about 650 foods (food categories - cereal, cookies, crackers, pizza and deserts) involved 100,000 man hours
    - Efforts continue to further reduce saturated and trans fat by developing new fats/oils and technology

Unintended consequences of focus on a single nutrient

- Fats
  - Consumers not monitoring caloric intake while consuming low-fat products leading to increased calorie consumption (Snackwells effect)
  - Reduction of saturated fats by replacement of tropical oils with partially hydrogenated oils
  - Current replacement of partially hydrogenated oils by saturated fat

- Sodium
  - Reduced safety barriers in some low-sodium foods (In UK some reformulations had to be reversed)
  - Lower palatability driving consumers to foods high in sodium

Unintended consequences of focus on a single nutrient (cont.)

- Sugars
  - May not reduce caloric intake, ingredient substitution may end up with the same/higher number of calories
  - May lead to higher intake of other macronutrients or food groups (e.g., solid fats, refined carbohydrates)
  - May lead to less palatability and perhaps lower consumption of some nutrient-dense foods (e.g., vegetables, breakfast cereals, yogurt, flavored milk, and cranberries)
    - Elimination of flavored milk in schools leading to reduction in milk consumption
  - Added sugars on the label – there is a potential to add to consumer confusion by providing too much information on the label and misleading consumers into thinking that added sugars have a unique health impact above and beyond total sugars

Nutrient contributions from packaged foods

- Studies show that the nutrient contribution of foods and not the level of processing should be considered while selecting foods.
  - Eicher-Miller et al., (2012):
    - "Processing level was a minor determinant of individual foods' nutrient contribution to the diet and, therefore, should not be a primary factor when selecting a balanced diet."
  - Dwyer et al., (2012):
    - Processed fruits and vegetables (e.g., canned, dried, frozen) made significant nutrient contributions (e.g., fiber, folate, potassium, vitamins A and C) to the diet
    - Processed foods also contributed to intakes of sodium and added sugar
  - Fulgoni et al., (2011):
    - Enrichment and/or fortification of foods improves the intakes of vitamins A, C, D, thiamin, iron and folate

Some additional thoughts…from a 40-year food science/food industry veteran

- Over 30 years of dietary advice have had minimal effect on obesity and other food related diseases in U.S.
- Focus on single nutrients and “avoiding x” often leads to higher consumption of other macronutrients of concern.
- Consumers may respond better to messaging on what to consume more of; e.g.
  - More complex carbohydrates and fiber vs. sugars
  - Diet vs. sugar-sweetened beverages
  - More potassium than sodium/salt
  - More MUFA than SFA

Summary

- Food science operates across a complex farm to fork system transforming raw food materials and ingredients into safe, nutritive, palatable, and affordable foods.
- Food technologists strive to help Americans achieve the dietary guidelines recommendations and improve human health.
- Food industry efforts have been successful in reducing calories, sodium, sugars, saturated fats, trans fat from foods while also increasing dietary fiber, and other micronutrients of concern.
- It may be productive to educate consumers on the nutrient contributions of various foods so they can make informed choices based on available food options rather than recommend limiting processed foods in their diets.

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