Conducting Research at the Interface of Food Science and Nutrition

The Babcock-Hart Award is given by the Institute of Food Technologists (IFT) to recognize food technology contributions that resulted in improved public health through nutrition or more nutritious food. I was happy to receive this scientific achievement award in 2018 for exceptional, pace-setting, focused, and innovative contributions made on the enzymatic modification of lipids to produce *trans*-free fats suitable for commercial applications in margarines, spreads, shortening, and baking, and for the development of various infant formula fats to improve infant nutrition and health. My experiences in writing grants and conducting research on projects that yield molecules with functionality in foods and potential health benefits are discussed, with the hope to inspire other scientists.

Establish Research Focus or Foci

I must say that a basic and sound background in biochemistry with good understanding of the biosynthetic and metabolic pathways, synthetic organic chemistry, and food chemistry play a key role on how I determine what kind of research to pursue. I apply the organic chemistry and biochemistry knowledge that I acquired in addition to the two years of postdoctoral research in animal and human nutrition to solve food science problems that would benefit health. *The end goal has always been – how would this research or molecule benefit human or animal health when consumed?* I believe that in order to be successful in research and leave a mark, you must focus on a specific area of inquiry, be driven, be eager to contribute to knowledge, and be passionate about the outcome or application of the research. I always ask myself, "what can I contribute to advance knowledge, to food science, to benefit the food industry and the consumer, and to improve health?" After identifying the general area, I read the literature and identify the critical gaps that need to be filled to advance the science. The next question is: would this be a sustainable long-term project? Also, is the research innovative, new, or a novel contribution to advance knowledge or solve a problem? Is it relevant to the food industry, or to the consumer in terms of human or animal health? Is this best accomplished using basic research, applied research, or a combination of basic and applied? In deciding which approach to take, one must not forget the underlying fundamental principles and mechanistic considerations in the approach to the project/problem.

Grant Writing – Potential Health and Food Application Considerations

I fully understand that the way research funding is appropriated currently is different from what it used to be. In the past, investigator-initiated proposals, or single-investigator projects, and two or more investigator projects were encouraged, and they often receive a substantial amount of funding to solve a research problem. To be a successful investigator with sustainable project(s) on functional benefits of foods/ingredients that would impact health, some of the following ideas and pointers that I use may be applicable to you as you seek funding:

- Articulate a long-term research agenda or focus area
- Establish long-term, topic-based research focus or foci
- Have an eye for hot topics, future direction of research in your field, and consumer interests
- Know the current and relevant issues in food science and technology research with potential benefits to nutrition and health
- Your request for funding and pursuit of basic and applied science must be balanced in accordance with the goals of the funding source
- Be cognizant that what is relevant today may be obsolete tomorrow
- You must adapt to change in a smart way
- Do not deviate much from your focus and expertise
- Embrace new technologies
- Realize that contributing to our understanding of basic principles and the mechanistic basis of your research problem require long-term projects that are sustainable with a constant quest for funding
- Do not be afraid to carve or initiate a niche research area for yourself
- Aspire and work to be the leader in your research area
- Do not hesitate to define new frontiers for future research in that area

Collaborative Research

Successful grant funding in recent years requires different types (sometimes ad-hoc) of collaborations within and outside your department (for example, Nutrition, Animal Science, Chemistry, Statistics, Horticulture, Pharmacy departments, and so on) and outside your university. *Meaningful collaboration among scientists with complementary research interests (not duplicative) stand a better chance of funding than proposals from scientists with similar (non-complementary) expertise.* Cross-disciplinary research (example, Food Science and Nutrition; Food Science and Chemistry; Food Science and Physics or Horticulture) may lead to major breakthroughs in science. It is obvious that USDA promotes interdisciplinary research with the understanding that a single investigator cannot or may no longer solve all research problems. To be successful in this environment, mission- or focus-oriented interdisciplinary research may be the key. The focused research topic must involve many different approaches that preclude a single investigator from having all the expertise and equipment needed to solve the research question. In this case, the research may require international collaborations, which often yield dividends such as joint publications and even future joint proposal writings. *Leveraging the expertise of your co-PIs and instrumentation available in their laboratories increases the chance of receiving grant funds and successful execution of the project objectives.* One important element to collaborative research is networking

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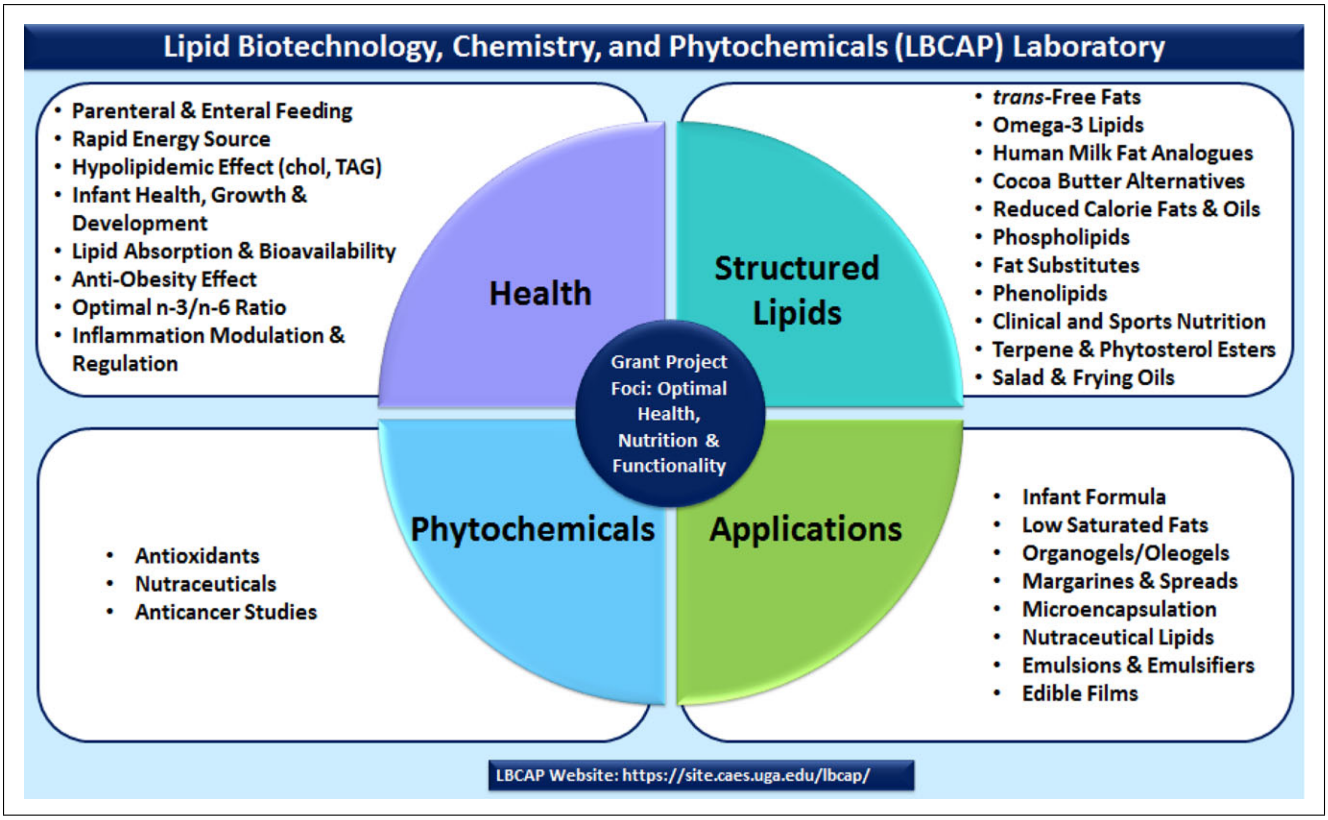

Figure 1–Lipid biotechnology, chemistry, and phytochemical (LBCAP) laboratory at the Univ. of Georgia.

at professional meetings where you can meet, cultivate, build relationships, and nurture them for future research and grant collaboration. Unfortunately, young investigators are at a disadvantage on projects with emphasis on multi-investigator funding mechanisms, in part because they have not yet built a good network.

I strongly encourage food scientists to take study leave or sabbatical to explore new and emerging areas of research and strengthen their research portfolio. I went to Academia Sinica, Taiwan, in 2004 (Akoh, Chang, Lee, & Shaw, 2008; Akoh, Lee, & Shaw, 2004; Akoh, Lee, Liaw, Huang, & Shaw, 2004) and Technical University of Denmark in 2017 (Hermund, Heung, Thomsen, Akoh, & Jacobsen, 2018; Jacobsen, Sørensen, Holdt, Akoh, & Hermund, 2019; Yesiltas, Garcia-Moreno, Sørensen, Akoh, & Jacobsen, 2019). There were other 2- to 3-month short stays in several universities in China, Thailand, and Taiwan, and some 1- to 3-week stays in other countries that helped my research program grow. I have hosted international visiting scientists, students, and postdoctoral students in my laboratory, and encourage you to do so in your laboratory as well as visit international labs on short-term basis.

Active collaborative research between university, industry, and government should be encouraged by the stakeholders through funding mechanisms of the grant agencies, provided each party/stakeholder has something to contribute and to benefit from the research outcome. Obviously, industry prefers applied research with short time turnaround, but in most cases the basic research must come before the applied aspect. Collaboration among many unrelated disciplines makes political sense for government funding but may not always contribute much to advance basic science.

Relating Food Science Research to Nutrition

Figure 1 illustrates what we do in our laboratory (lipid biotechnology, chemistry, and phytochemicals, LBCAP) in terms of lipid modifications and phytochemical research, while Figure 2 highlights how the results of our research are related to nutrition in terms of metabolism and potential health benefits (Akoh, 2004). The nutritional properties of lipids strongly depend on their fatty acid and triacylglycerol or glycerophospholipid (TAG or GPL) composition, fatty acid position on the glycerol backbone, and their molecular species (Chapkin, Akoh, & Miller, 1991; Liang et al., 2018). Structured lipids (SL) can be designed for nutrition, medical, nutraceutical use (healthful lipids), or for functionality in foods (Akoh, 2004; Akoh & Kim, 2017; Kim & Akoh, 2015; Osborn & Akoh 2002; Pande & Akoh, 2012):

- **Physicochemical and functional properties**: Lipids with desirable properties such as melting, rheology, plasticity (Seriburi & Akoh, 1998), oxidative and frying stability, emulsification, *trans*-free alternative (Jennings & Akoh, 2010; Kadamne, Moore, Akoh, & Martini, 2018; Kim, Lumor, & Akoh, 2008; Lumor et al., 2007; Pande, Akoh, & Shewfelt, 2012), and edible films are being produced. These include cocoa butter alternatives (Bahari & Akoh, 2018a,b; Jin, Akoh, Jin, & Wang, 2018; Osborn & Akoh, 2002), margarines, spreads (Kim, Shewfelt, Lee, & Akoh, 2005), shortenings, baking fats (Agyare, Addo, Xiong, & Akoh, 2005; Agyare, Xiong, Addo, & Akoh, 2004), salad oils (Fomuso, Corredig, & Akoh, 2001), flavor or terpene esters (Claon & Akoh, 1994; Wu, Akoh, & Phillips, 1996), organogels, and edible films (Moore & Akoh, 2017; Sellappan & Akoh, 2000) (Figure 1).

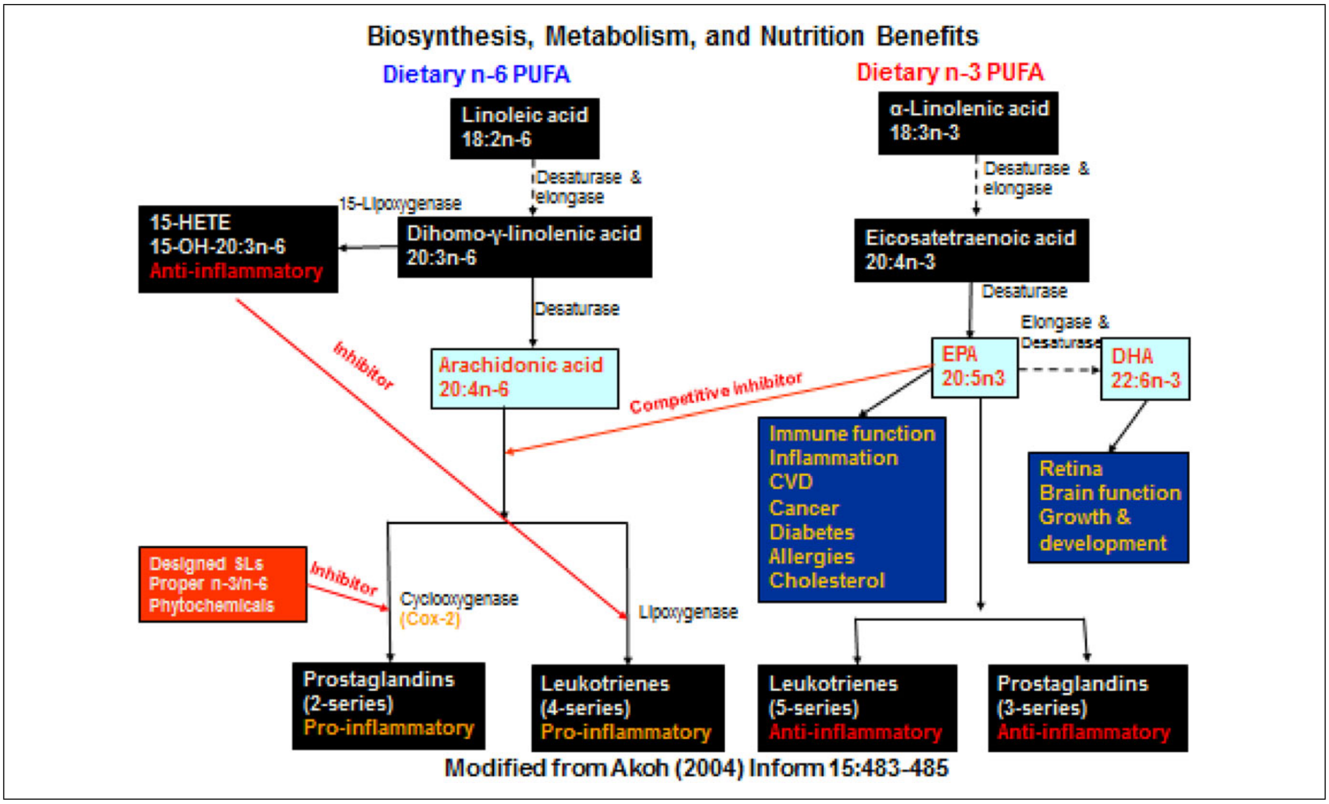

Figure 2–Biosynthesis, metabolism, and nutrition benefits of designed lipids and phytochemicals.

- **Healthful lipids** are being designed for better absorption, reduced calories, disease considerations, immune function modulation, cholesterol reduction, enteral and parenteral nutrition, balanced n-3/n-6 ratio (Jennings & Akoh, 1999), reduction or removal of *trans* fats, infant growth and development (Zou, Pande, & Akoh, 2016), and fat substitutes (Akoh, 1995, 1998). Examples include:
  - Structured lipid containing conjugated linolenic acid, CLA (Lee, Lee, Akoh, & Kim, 2006)
  - Lipids with enhanced absorption of palmitic acid also known as β-palmitate (palmitic acid at the *sn*-2 position of the triacylglycerol) for infant formula (Nagachinta & Akoh, 2013b; Teichert & Akoh, 2011) (Figure 2).
  - Medium-long-medium chain SL (nutraceutical lipids for sports and clinical nutrition) (Jennings & Akoh, 2001; Lee, Akoh, Flatt, & Lee, 2000)
  - Human milk fat analogues (Nagachinta & Akoh, 2013a; Sahin, Akoh, & Karaali, 2005)
  - Phytosterols esters (Kim & Akoh, 2006; Kim, Sandock, Robertson, Lewis, & Akoh, 2007)
  - Modified phospholipids (Mutua & Akoh, 1993)
  - Lipids with potentially enhanced absorption of physiologically important fatty acids (gamma linolenic acid, GLA (Lumor & Akoh, 2005); stearidonic acid, SDA (Teichert & Akoh, 2011))
  - Lipids for enhanced immune modulation such as eicosapentaenoic acid, EPA (Lee, Akoh, & Dawe, 1999), allergies, and improved cardiovascular function
  - Lipids for infant nutrition such as docosahexaenoic acid (DHA) for cognitive and brain function, retina, and growth and development of infant (Sahin Yesilcubuk & Akoh, 2017; Zou et al., 2016)
  - Anti-inflammatory lipids (Chapkin, Akoh, & Lewis, 1992) that produce anti-inflammatory eicosanoids (leukotrienes and prostaglandins) and phytochemicals that modulate inflammation

Microencapsulation was used to prevent oxidation of long-chain polyunsaturated fatty acids in SL and in their food applications (Ifeduba & Akoh, 2015, 2016; Nagachinta & Akoh, 2013c; Sproston & Akoh, 2016).

Many phytochemicals have antioxidant ability (Pastrana-Bonilla, Akoh, Sellappan, & Krewer, 2003; Sellappan, Akoh, & Krewer, 2002) and some have anticancer properties (Dulebohn et al., 2008; Yi, Akoh, Fischer, & Krewer, 2006a,b) (Yi, Fischer, Krewer, & Akoh, 2005; Figure 1). They can inhibit cyclooxygenase and prevent production of inflammatory leukotrienes and prostaglandins (Figure 2). Likewise, lipids with balanced n-3/n-6 ratio or SL with appropriate fatty acids (for example, EPA) are immunomodulatory and can affect allergies, cancer, and inflammation as anti-inflammatory compounds. Potential applications and health benefits of the designed structured lipids are listed in Figure 1.

Most of our work involved collaboration with faculty in my department (food science & technology), department of animal science, food and nutrition, chemistry, horticulture, and college of veterinary medicine. I have also collaborated with scientists in other areas such as biotechnology, genetic engineering, sensory, as well as government scientists, and so on, including scientists from other universities within and outside the US. Only samples of such collaborations are cited in this essay.

Research Findings Must Be Disseminated and Published

The university is a training ground for future researchers and industry personnel. Efforts should be made to disseminate the research findings to the public through seminars, conference presentations, peer review articles, and reports to the sponsors.

Why publish: You publish to make contributions to science and society, for professional recognition, and to advance in your field or profession. If you have a funded grant, especially public funding from, say, NIH, USDA, or NSF, it is an obligation to honor and execute the contract by fulfilling the objectives of the project and report back to the funding agency as well as publish your findings in scientific journals. Researchers must be held accountable for what they said they would do with the grant money (public or private industry funds). In order to continue to receive funding from government or industry to sustain your research program, a report and publication of your findings are expected. Research findings are of no use if they sit in your drawers and are not published and disseminated.

To conduct good research, the researcher must have access to the necessary instrumentation and space. If not available, there should be no excuse for not seeking out other researchers on campus, government research laboratories, industry, and universities within and outside your country. This could be in the form of collaboration or fee for analysis. I believe you should take enough time to carefully plan the experiments, have adequate sample size to enable statistical analysis of your data, and make sure there is new information to be obtained from the experiments. *A well-thought-out and designed experiment is more important than a well-executed experiment that was not carefully planned*. It is important that your work can be repeated by others, and that is a way to increase the citation of your publication. Always ask if this research and publication will advance knowledge in the area the research was conducted. Is the research a novel contribution? Was it written in a simple and understandable language? It is possible that industry can pick up published research results and use them for application in real food products to benefit nutrition and health.

Summary

This essay was intended to give readers some insight into my research program. Another objective was to share my wisdom on how to look for grants, which allowed me to conduct food science research with potential nutritional benefits. I hope that the limited examples I gave will help other scientists, especially young scientists, to be focused, conduct collaborative research with others around the world, plan their research careers, and be successful.

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