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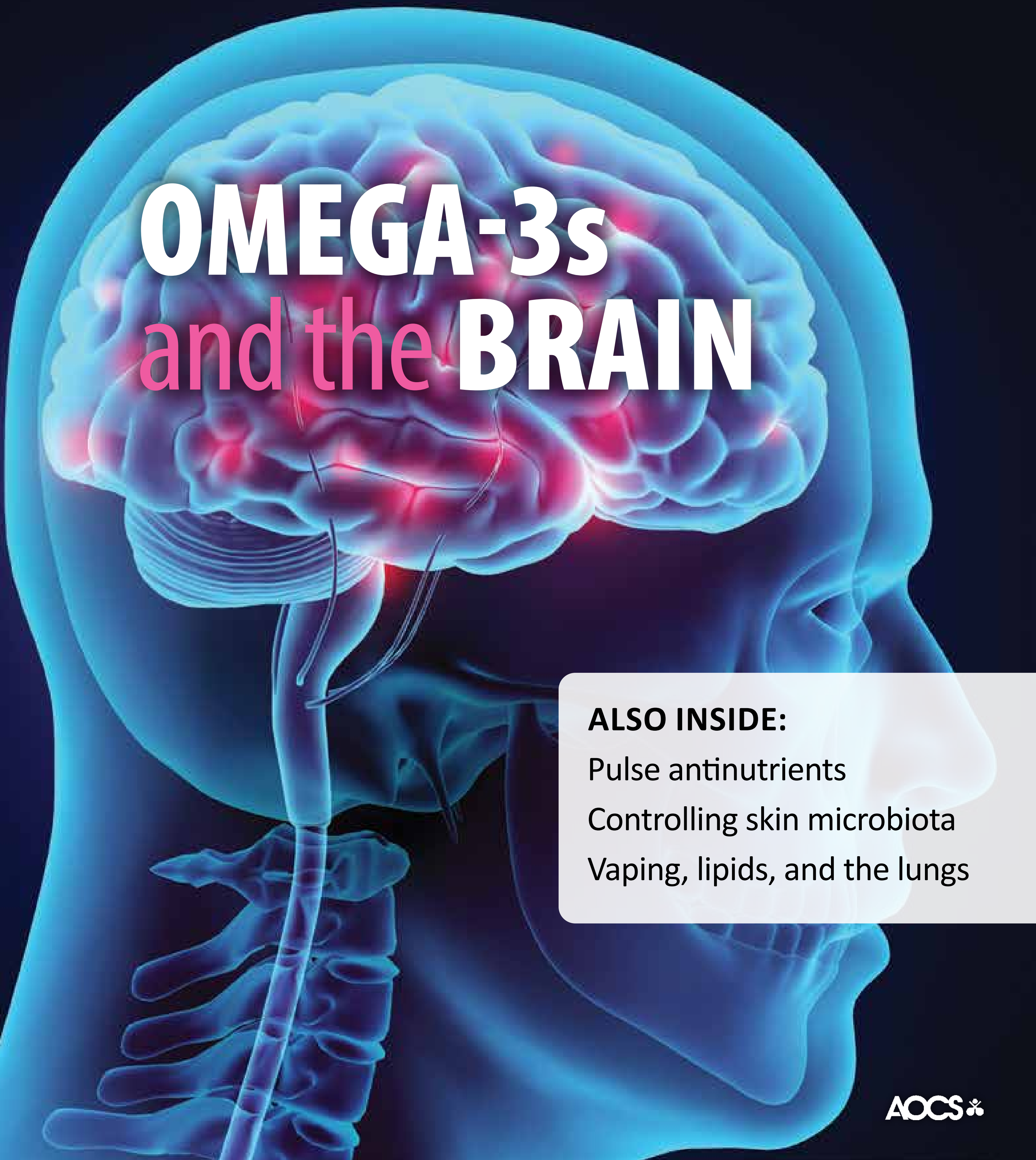

OMEGA-3s and the BRAIN

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The trouble with studying omega-3s and the brain

Rebecca Guenard

The US-based pharmacy CVS was recently ordered to refund the purchase price (about $31.00) of a falsely advertised dietary supplement. The pharmacy claimed the plant-derived form of the omega-3 fatty acid, docosahexaenoic acid (DHA), was clinically proven to improve memory. The advocacy group Center for Science in the Public Interest argued that CVS based its claim on research that, on the contrary, did not indicate that omega-3s boost cognitive function.

- **Omega-3 research on the heart has suggested that the fatty acids positively benefit the cardiovascular system by controlling blood clotting and building cellular membranes.**
- **Although researchers have established that omega-3s are crucial for neural and vision development during pregnancy and the first few years of life, they have not yet determined how or if omega-3s help with brain function as we age.**
- **Some researchers question whether the fatty acid can even cross the blood-brain barrier. There is currently no way to know, but a new imaging technique may reveal the answer.**

Health organizations around the world strongly recommend eating food rich in omega-3, since research indicating a benefit to the cardiovascular system continues to strengthen. However, it is less clear what the brain can garner from this group of fatty acids. Richard Bazinet, associate professor of nutritional science at the University of Toronto in Ontario, Canada, says that 30 years ago researchers noticed that infants who were breast fed had higher levels of docosahexaenoic acid (DHA) in the brain than infants who consumed formula. At the time, infant formula was not supplemented with the fatty acid. That observation sparked more research on the compound's purpose in the brain and the nutritional choices that ensure a sufficient supply.

"Preclinically, this was easy," Bazinet says. "Lowering brain DHA levels in animals shows that the molecule is very important in regulating a lot of brain functions. Nutritionally in humans, this gets really complicated."

The 1994 study of infant brain tissue proved that DHA concentration could be altered by nutrition, presumably affecting a range of health issues. Over the past three decades, studies have sought to answer whether polyunsaturated fatty acids (PUFAs) in the diet can improve intelligence, reduce depression, minimize symptoms of schizophrenia, or slow the progression of Alzheimer's disease. Through three decades of research, there have been mixed or slightly positive results on the brain benefits of omega-3s. After all this time, what have we learned about the function of fatty acid in the brain and the foods that help humans achieve a health benefit?

FUNCTION

The human brain is primarily composed of fat. Phospholipids account for almost half of the organ's weight. One of the most important structural molecules is the fatty acid DHA, which comprises the cerebral cortex, synaptic membranes, mitochondria, retina photoreceptors, and more. Humans acquire omega-3s during development, but several factors determine the production of omega-3s throughout life.

For the first few years of life, humans are dependent on their mothers for essential fatty acids (Fig. 1). The fetus acquires DHA from maternal diet and the mother's stored lipids. In the final trimester, maternal DHA

levels drop dramatically as the fetus needs about half a gram a day to form its retina, liver, and brain. At birth, the human brain is about 70% developed and continues to grow for about six years. Infants obtain fatty acids from their diet. Human milk contains 30 times the DHA levels of milk from other animals. Since the 1990s, these crucial compounds have also been added to infant formula.

"We understand what the molecule does in the brain," says Bazinet. "However, we do not understand very much about the regulation of brain levels in adults and how much nutrition you need to maintain those levels."

Beyond the preschool years, humans have the metabolic capacity to synthesize specific omega-3s from the diet as needed, and no longer require a direct supply. Along with DHA, other nutritionally important omega-3 PUFAs, like eicosapentaenoic acid (EPA) and docosapentaenoic acid (DPA), are synthesized by an enzymatic desaturation of alpha-linolenic acid (ALA).

Though the mechanisms for formation are well-understood, they are less predictable inside the human body. For example, genetics can influence the speed and efficiency of these reactions. One study found that subjects with a desaturation gene variant convert ALA to important omega-3s more

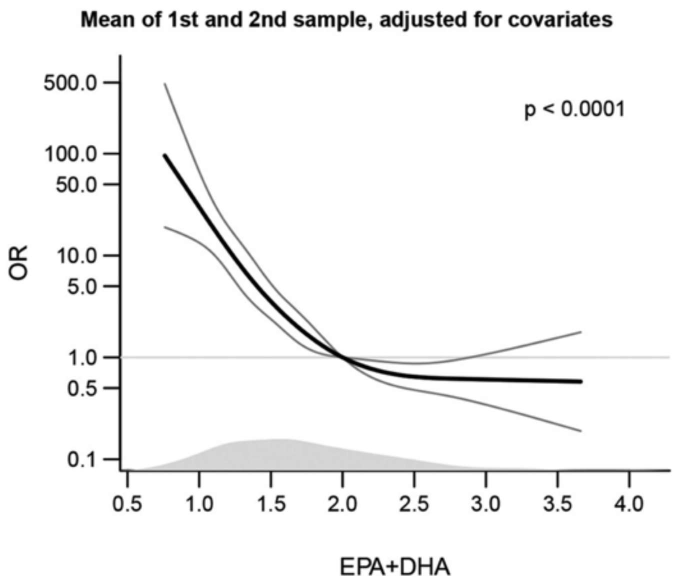

FIG. 1. A graph showing the importance of two types of maternal omega-3 concentration in blood plasma. The lower the concentration, the lower the odds of the mother carrying the baby to term. Source: Olsen, *et al.*, *EBioMedicine,35*: 325, 2018.

slowly than those without the variant, implying that supplementation may be effective at increasing omega-3 concentrations in the blood of some individuals, but not in others.

However, the amount of omega-3s in a person's blood does not indicate the amount of omega-3s in the brain. To get an idea of how much of these molecules are in the brain, scientists rely on animals. Mouse studies show that omega-3 synthesis is rare in the brain and that levels are maintained by an accumulation in blood plasma from dietary sources. Both EPA and DHA appear to cross the blood-brain barrier in mice, but only DHA is detectable among the brain's phospholipids.

"Despite not being detectable, new studies suggest that EPA gets in the brain and then gets metabolized very quickly," Bazinet says. A recent study shows that EPA is metabolized into DHA and thus could be the key to reaping the benefits of this important omega-3. Some researchers believe EPA could alleviate a variety of brain-related ailments.

MENTAL HEALTH

Early studies on brain development and DHA revealed that maternal levels plummet at birth, which may be responsible for postpartum depression. Maternal plasma DHA levels drop by as much as 50% and may take up to six months to recover after delivery. Postpartum analysis of rats' brains found that maternal brain DHA content after a single litter of pups can decrease by as much as 25% of its original level. The finding provoked further research into the role of DHA in mental health, revealing the importance of the compound for regulating dopamine.

The presence of PUFAs in brain membranes serve a variety of functions pertaining to neurological signaling. DHA is among a series of nuclear receptor ligands that participate in multiple transcription pathways involving dopamine. Neuronal and synaptic membranes contain high concentrations of DHA. The compound affects ion permeability, elasticity, protein function, phase behavior, and fusion. A range of studies confirm DHA's involvement in the development and survival of dopamine systems within the brain.

Both animal and human studies indicate that omega-3 deficiencies during early brain development can alter dopamine upkeep in the organ, leading to disorders like ADHD, depression, or schizophrenia (https://doi.org/10.2174/1871527317666180412153612). Researchers looked at specific tissue within the blood of schizophrenic patients and found that, compared to controls, they contain a lower amount of omega-3s. Low dietary and tissue levels of omega-3s in rodents have also consistently correlated with neurobiological indicators of depression. And some clinical trials involving symptomatic patients treated with omega-3 preparations have shown positive outcomes.

Antipsychotic drugs function by targeting dopamine receptors, and researchers theorize that some mental illness may result from an overactive dopamine system. By extension, omega-3s that assist in regulating dopamine are likely to help. Adult rats gestated and raised on omega-3-deficient diets showed a 70% reduction in brain DHA levels, and several areas of their dopamine system were defective. This has led many researchers to consider whether omega-3s should be incorporated in treatments for various mental health disorders.

However, in November 2019, a team of researchers at the University of East Anglia, United Kingdom, funded by the World Health Organization, published the results of a random-effects meta-analysis evaluating 31 clinical trials that assessed the effectiveness of long-chain omega-3 supplements in treating depression (https://doi.org/10.1192/bjp.2019.234). "Oily fish can be a very nutritious food as part of a balanced diet," said Katherine Deane, the paper's lead author. "But we found that there is no demonstrable value in people taking omega-3 oil supplements for the prevention or treatment of depression and anxiety."

Despite all the evidence of DHA's participation in crucial mechanisms of mental health, the finding on supplements indicates a gap in scientific understanding about how consuming omega-3 fatty acids can improve membrane concentrations established during development.

COGNITION

The recent, successful lawsuit against CVS pharmacy highlights the many questions still swirling around omega-3s and the brain. Due to the participation of these molecules in the growth and repair of new neurons, researchers have assumed that omega-3 supplementation could prevent cognitive decline. The anti-inflammatory effect of fatty acids increase support for this hypothesis. Yet, as with other biological mechanisms involving omega-3s, there is little evidence showing cognitive improvement with supplementation.

New neurons are generated in the brain by different types of cells, but as we age, this process, called neurogenesis, slows down. This slowing is accompanied by a decline in neuron maintenance. Animal studies have shown that EPA and DHA increase the growth of neurons in the developmental stage, but for aged rats, only DHA initiates improvements. These findings have inspired researchers to determine if neurogenesis and neuron survival could be improved in adult humans. However, many clinical studies have shown no difference between participants given treatment versus baseline scores for cognitive measures.

"I don't think anybody thinks omega-3s will increase your memory," Bazinet says. "The idea is it will delay the decline in your memory with time." He adds that quantifying such an effect is difficult to do since there will be no memory change in most adults during the duration of a clinical trial. "You have to look for people who are just starting to decline and test it in them," he says. "It is a very hard thing to do."

Here again, genetics complicates any study aimed at determining if omega-3s improve thinking and memory. Carriers of the ApoE-ε4 gene are more likely to develop late onset Alzheimer's disease. This cohort also shows a lower response to EPA and DHA, and they are also less likely to experience improved cognitive function from eating fish. Scientists do not yet have a complete understanding of the gene and what it does, and more research is needed to fully understand its contribution to brain function with age.

One effect of aging that is better understood is the brain's tendency toward inflammation. Studies of aged rats fed an EPA and DHA enriched diet concluded that the omega-3s had

TABLE 1. Results from randomized clinical trials (RTCs) between 2005 and 2012 indicating that omega-3 supplementation has shown no health benefit in most analyses, contrary to studies of fish consumption. However, researchers want to know if eating fish is the cause of improved health or simply a correlation. Source: Grey *et al.*, *JAMA Intern. Med. 174*: 460, 2014.

Source	Design	Intervention	No.	Primary Outcome	Result	Editorial Score[a]	News Stories[b]
Studer *et al.*, 2005[3]	Meta-analysis RCT	ω-3 FA	20 260	Mortality[c] Cardiac mortality Noncardiac mortality	Benefit Benefit No benefit	...	0
Raitt *et al.*, 2005[4]	Double-blind RCT	Fish oil	200	Ventricular arrhythmia	No benefit	...	12
Hooper *et al.*, 2006[5]	Meta-analysis RCT	ω-3 FA	33 625 33 193 31 255 17 433	Cardiovascular events[c] Mortality Stroke Cancer	No benefit No benefit No benefit No benefit	3	24
Brouwer *et al.*, 2006[6]	Double-blind RCT	Fish oil	546	Ventricular arrhythmia or mortality	No benefit	...	1
Yokoyama *et al.*, 2007[7]	Open-label RCT	EPA	18 645	Major coronary events	Benefit	5	13
Feagan *et al.*, 2008[8]	Double-blind RCT	ω-3 FA	738	Relapse of Crohn disease	No benefit	...	9
Tavazzi *et al.*, 2008[9]	Double-blind RCT	ω-3 FA	6975	Mortality Mortality or cardiovascular hospitalization	No benefit[d] No benefit[d]	5	26
Leon *et al.*, 2008[10]	Meta-analysis RCT	ω-3 FA	1148 31 111 32 159 32 439	Ventricular arrhythmia Sudden cardiac death Cardiac death[e] Mortality[e]	No benefit No benefit Benefit No benefit	4.5	2
Makrides *et al.*, 2009[11]	Double-blind RCT	DHA	657	Neurodevelopment	No benefit	5	13
Carney *et al.*, 2009[12]	Double-blind RCT	DHA + EPA	122	Depression score	No benefit	...	8
Galan *et al.*, 2010[13]	Double-blind RCT	ω-3 FA	2501	Cardiovascular events	No benefit	...	0
Makrides *et al.*, 2010[14]	Double-blind RCT	DHA	2399 726	Postpartum depression Neurodevelopment	No benefit	...	27
Kromhout *et al.*, 2010[15]	Double-blind RCT	ω-3 FA	4837	Cardiovascular events	No benefit	...	13
Kowey *et al.*, 2010[16]	Double-blind RCT	ω-3 FA	663	Atrial fibrillation	No benefit	...	7
Quinn *et al.*, 2010[17]	Double-blind RCT	DHA	402	Cognitive function	No benefit	1.5	17
Rice *et al.*, 2011[18]	Double-blind RCT	ω-3 FA, linoleic acid, and antioxidants	272	Assisted ventilation	No benefit	2.5	1
Palmer *et al.*, 2012[19]	Double-blind RCT	DHA + EPA	706	Allergic diseases	No benefit	...	0
Andreeva *et al.*, 2012[20]	Double-blind RCT	ω-3 FA	2501	Cancer	No benefit	...	12
Lok *et al.*, 2012[21]	Double-blind RCT	Fish oils	201	Hemodialysis graft patency	No benefit	4	3
Bosch *et al.*, 2012[22]	Double-blind RCT	ω-3 FA	12 536	Cardiovascular events	No benefit	...	8
Chowdhury *et al.*, 2012[23]	Meta-analysis RCT	ω-3 FA	62 040	Cerebrovascular disease	No benefit	4	17
Kwak *et al.*, 2012[24]	Meta-analysis RCT	ω-3 FA	20 485	Cardiovascular events	No benefit	4	14
Rizos *et al.*, 2012[25]	Meta-analysis RCT	ω-3 FA	63 279 56 407 41 751 53 875 52 589	Mortality[c] Cardiac death Sudden death Myocardial infarction Stroke	No benefit No benefit No benefit No benefit No benefit	1.5	17
Mozaffarian *et al.*, 2012[26]	Double-blind RCT	ω-3 FA	1516	Atrial fibrillation	No benefit	...	5

Abbreviations: DHA, docosahexaenoic acid; ellipses, no editorial was written; EPA, eicosapentaenoic acid; FA, fatty acid; RCT, randomized clinical trial.

[a] Disposition of the editorial comment toward use of fish oil or ω-3 FAs was scored independently by each author on a numeric scale: 1, clearly unfavorable; 2, mixed, overall unfavorable; 3, neutral; 4, mixed, overall favorable; and 5, clearly favorable. Interobserver difference did not exceed 1 point for any editorial. Data are mean scores.

[b] Number of news stories generated within 2 weeks of publication.

[c] No hierarchy of end points was described.

[d] No statistically significant results in unadjusted analyses, but the authors reported a nonstandard adjusted analysis as the main finding.

[e] Specified as secondary end points.

a clear anti-inflammatory effect. Another study performed on Alzheimer's patients produced a similar result. Inflammatory markers like cytokines were significantly lower in patients who consumed a daily dose of EPA or DHA.

Still, deciphering the results of omega-3 studies can be tricky. As Bazinet mentioned, comparing preclinical studies on mice to clinical trials involving human plasma or tissue makes it challenging for researchers to draw overarching conclusions or dietary recommendations. Take fish studies, for example. It is unclear if simply eating fish improves health or if fish eaters have a higher socioeconomic status and cleaner lifestyle than non-fish eaters (Table 1, page 9).

"There are a lot of studies that look at groups of people that eat fish," Bazinet says. "The results look good, but this is a correlation, cause and effect are hard to determine." From a public health perspective, the cause is irrelevant, he says. If routinely eating fish reduces inflammation and improves cardiovascular health, then experts should encourage people to eat fish. As a scientist, Bazinet says he wants to understand more about why these benefits occur, so humans can maximize their potential.

IMAGING

John Georgiadis is a biomedical engineer at Illinois Institute of Technology in Chicago, Illinois, USA. He has been using a new brain imaging technique that is growing in popularity and could help nutritionists like Bazinet study omega-3s in the living brain. In magnetic resonance elastography (MRE), a minor palpation of the brain during a typical scan reveals properties of the tissue that cannot be assessed otherwise. The resulting image is a map of tissue stiffness (https://doi.org/10.1016/j.neuroimage.2017.10.008).

Studies on healthy volunteers confirm that stiffness decreases with age. "You expect that with tangles and amyloid deposits the brain would be mostly hard material as we age," says Georgiadis. The contrary is true, he says, because the deposits disrupt connections that maintain overall stiffness. "You can have hard regions in the brain tissue, but the rest is loose."

Brain stiffness has been proven a strong indicator of cognitive performance and neurodegeneration. Studies show that stiffness decreases in diseases like multiple sclerosis and dementia. Additionally, the spatial pattern of stiffness and other viscoelastic properties indicate different brain ailments. Combined with other techniques, like diffusion tensor imaging (DTI), a highly sensitive type of magnetic resonance imaging (MRI) that maps water flow through white matter (https://doi.org/10.1016/j.nurt.2007.05.011), researchers can differentiate between brain changes at the microstructural and cellular level to evaluate if there is any effect from digested lipids.

Until now there have been few attempts to image DHA uptake in the living human brain, because the procedure required complicated radiochemistry to acquire images. The only other option would be a brain biopsy which, not surprisingly, researchers are not willing to conduct on healthy humans. Studies on post-mortem samples comparing fatty acid content of plasma and brain tissue from the same individual suggests that plasma levels are not reflective of fatty acid concentrations in the brain. Imaging an ingested molecule as it travels the brain would be ideal.

"It is too simplistic to assume that just because the brain has more lipids than protein, we can affect its lipid content," says Georgiadis. "The brain will do whatever it can to maintain function."

So far, he has not performed MRE studies focusing on lipids as an aspect of the diet, but his group is currently in the process of submitting proposals to study specific nutrients and their effect on brain structure. As researchers improve the protocols for imaging techniques like MRE and DTI, they can apply them to more dietary studies. Though, as Bazinet points out, dietary double-blind trials are still a challenge. "Either you get the fish, or you get the hamburger."

The brain stops accumulating DHA at around 18 months. Researchers believe that from conception to two years of age, the omega-3 fatty acid concentration can be increased by consumption; beyond that, they are not so sure. Their best assessment for omega-3 intake as we age is: It cannot hurt. Cardiovascular research indicates that omega-3s improve circulation, which means better blood flow to the brain and all the other organs. Consumers will have to be satisfied with that for now.

Rebecca Guenard is the associate editor of Inform *at AOCS. She can be contacted at rebecca.guenard@aocs.org.*

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Control of skin microbiota with fatty acids: rethinking the removal of *"all"* skin microorganisms

T. Nagao, A. Uyama, T. Sugino, S. Tanaka, and N. Kishimoto

- *Staphylococcus aureus*, *S. epidermidis*, and *Cutibacterium acnes* are harmful, beneficial, and intermediate microorganisms, respectively, in terms of human health.
- Sapienic acid (SA, 6-*cis*-C16:1) and palmitoleic acid (POA, 9-*cis*-C16:1) show selective antibacterial activity, with strong activity against *S. aureus* and weak activity against *S. epidermidis*.
- Pentadecanoic acid (C15:0) shows selective antibacterial activity, with strong activity against acne-associated *C. acnes* strains and weak activity against strains observed only in healthy individuals.

Humans live with many microorganisms. As these include beneficial microorganisms that contribute to health as well as harmful microorganisms associated with diseases, the killing or suppression of all microorganisms with antibacterial agents is not ideal. We briefly review a new approach for the control of the skin microbiota and the promotion of human health using fatty acids with selective antibacterial activity against harmful microorganisms.

SKIN MICROBIOTA

Humans have adapted to coexist with many microorganisms, since interactions with microorganisms residing in the natural environment are unavoidable. Owing to remarkable developments in genome analysis by next-generation sequencing, commensal microorganisms (bacteria, fungi, and viruses) in or on several organs, such as in the gut and oral cavity, and on the skin, have become a major focus of research [1]. Together, these commensal microorganisms are often referred to as the microbiome, microbiota, and flora. Figure 1 shows the huge estimated numbers of bacteria among the human commensal microorganisms observed in or on each organ.

Human skin microorganisms can be classified into four groups: beneficial microorganisms that contribute to health, harmful microorganisms associated with diseases, microorganisms with no or unknown functions, and intermediate microorganisms causing opportunistic infections (Fig. 2).

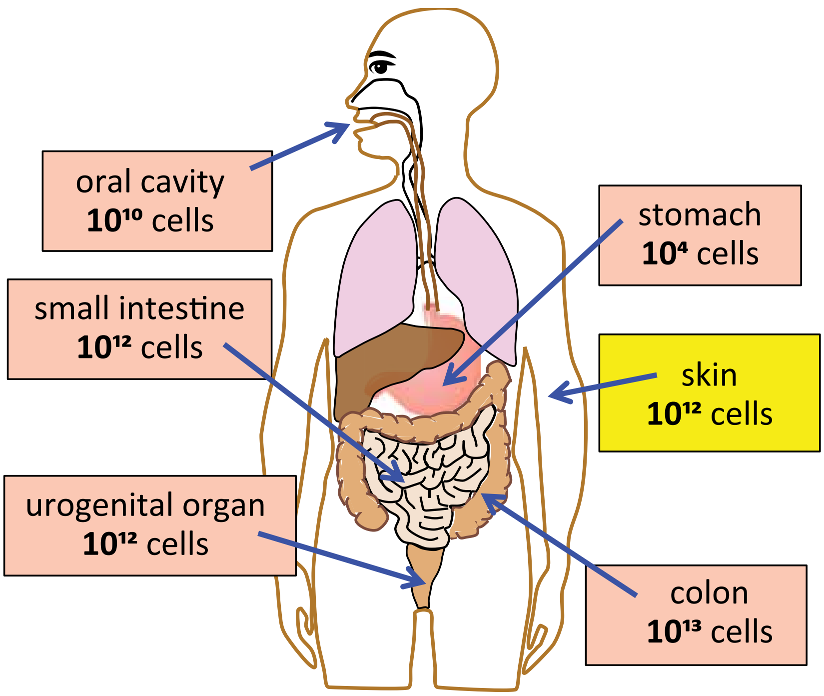

FIG.1. Estimated number of bacteria among human commensal microorganisms observed in or on each organ

It is commonly believed that microorganisms are dirty, cause bad odors, and should be *completely* removed. Many conventional antibacterial agents are aimed at killing or suppressing the growth of *all* microorganisms. However, is this the best strategy for improving human health?

As the largest organ in the human body, the skin is colonized by many microorganisms (about 10^{12} cells) and serves as a physical barrier to prevent the invasion of pathogens, such as undesirable microorganisms and ticks. This barrier is composed of commensal microorganisms, skin lipids, epithelial cells, tight junctions, and immune cells. When the barrier is broken, or when the immune

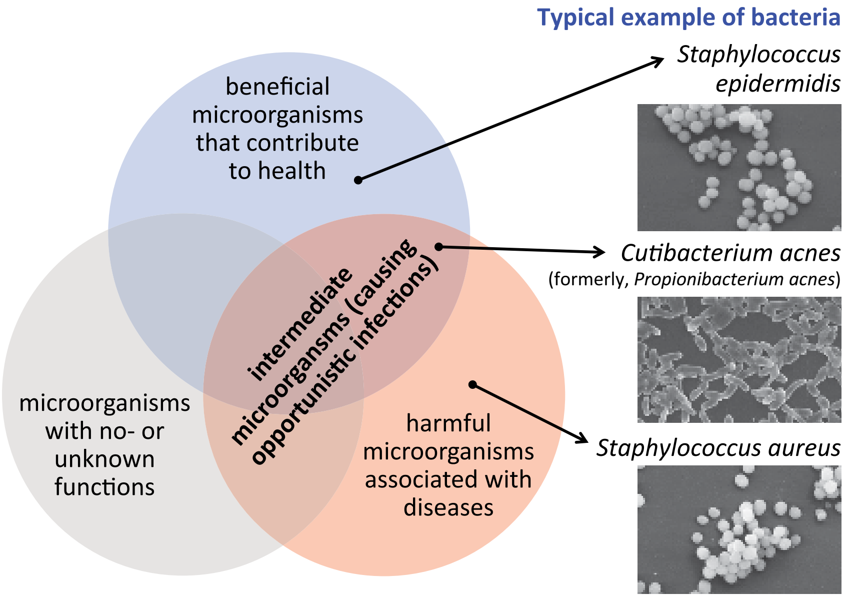

FIG.2. Classification of commensal microorganisms on human skin

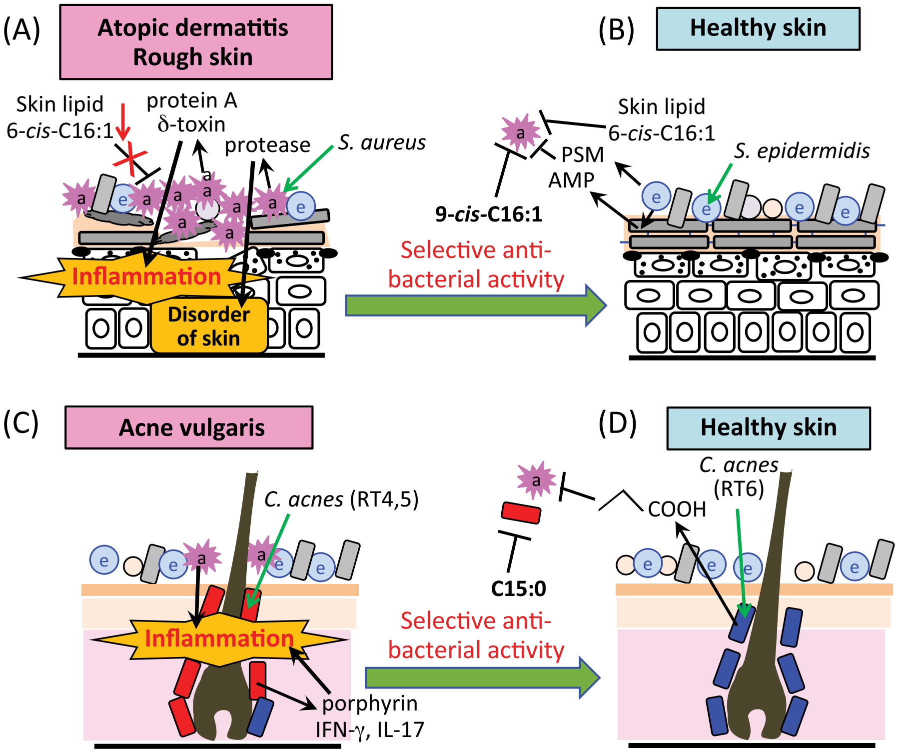

FIG.3. Control of skin microbiota with C16:1 or C15:0

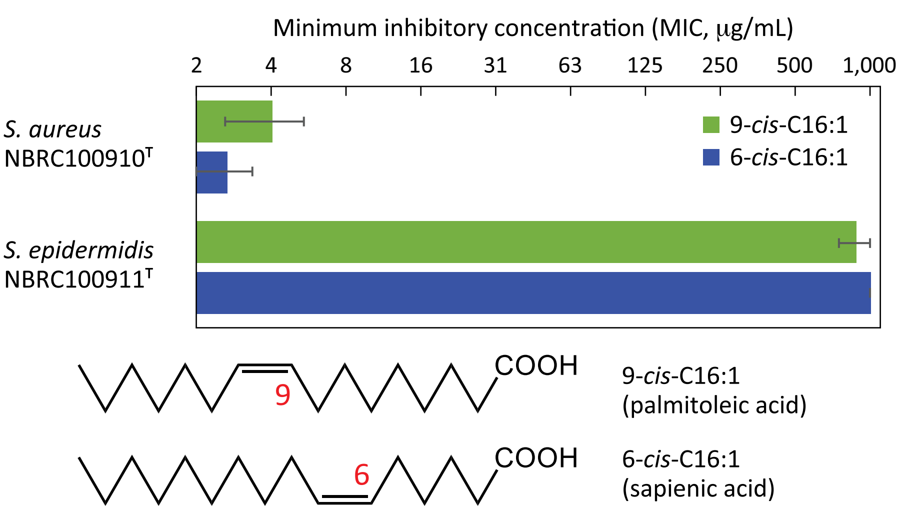

FIG.4. Antibacterial activity of palmitoleic and sapienic acids against *Staphylococcus aureus* and *S. epidermidis*

Betting on the microbiome

The science of the skin's microbiome is still being established, but beauty companies are already starting to develop products based on this concept. Learn more by reading "Feeding the skin microbiome" on page 10 in the October 2019 issue of *Inform* (https://www.informmagazine-digital.org/informmagazine/october_2019/MobilePagedReplica.action?pm=2&folio=10#pg12).

system fails, the balance between commensals and pathogens is disrupted, and skin diseases can result. Thus, it is appropriate to remove only harmful microorganisms associated with diseases, except in special cases (e.g., in hospital settings). This article briefly reviews two novel fatty acids that allow humans and harmless microorganisms to co-exist while killing or suppressing disease-causing bacteria.

STAPHYLOCOCCUS, ATOPIC DERMATITIS, AND SKIN LIPIDS

Staphylococcus aureus is a well-known pathogenic bacterium associated with many diseases and food poisoning. It is rarely observed on healthy skin (average 1.1% of total skin bacteria) but is detected at a high ratio (average 65%) [2] on the skin of patients with atopic dermatitis (AD), and aggravates inflammation by producing the proteins depicted in Figure 3A. These include: (1) Cell surface protein A, which stimulates the secretion of inflammatory IL-18, (2) delta-toxin, which activates mast cells, and (3) extracellular protease, which causes dysfunction of the epidermal barrier. Furthermore, *S. aureus* is frequently observed on the hands of healthcare workers in hospitals. This may be explained by a decrease in skin lipids from repeated hand washing.

Staphylococcus epidermidis is commonly observed on the skin of both healthy individuals and patients with AD. It has positive effects on skin health via the production of the following factors shown in Figure 3B. These positive effects include: (1) a small molecule protein (<10 kDa) increases antimicrobial peptide (AMP, beta-defensin) secretion by keratinocytes, (2) phenol-soluble modulin (PSM) inhibits the growth of *S. aureus*, (3) a serine protease inhibits biofilm formation by *S. aureus*, and (4) lipoteichoic acid (LTA) represses inflammatory cytokine release from keratinocytes. Accordingly, the selective suppression of skin microorganisms, that is, the repression of *S. aureus* growth but not *S. epidermidis* growth, is the best way to maintain skin health.

Sapienic acid (SA, 6-*cis*-C16:1), a human skin lipid, shows selective antibacterial activity, including strong activity against *S. aureus* and weak activity against *S. epidermidis* (Fig. 4). As the SA content (~2 µg/cm^2) decreases substantially on AD skin and after repeated hand washing, SA supplementation is expected to be an effective approach. However, SA is rarely observed in natural oils. We found that a double bond positional isomer of SA, palmitoleic acid (POA, 9-*cis*-C16:1), a component of several natural oils (fish oil, horse oil, tallow, macadamia nut oil, and sea buckthorn fruit oil) and single-cell oils from *Saccharomyces cerevisiae* and diatoms (*Phaeodactylum tricornutum* and *Nannochloropsis oceanica*), show similar selective antibacterial activity to that of SA (Fig. 4). As other selective antibacterial agents that can be easily sourced have not yet been found, POA is a promising new strategy to realize improved skin health via control of the skin microbiota. According to these findings, we developed a new ingredient for cosmetic products from a natural POA-containing oil, and a novel cosmetic product containing this component was commercialized on August 23, 2019.

ACNE VULGARIS AND *CUTIBACTERIUM*

Cutibacterium (formerly *Propionibacterium*) *acnes* is a major commensal bacterium residing on normal human skin and has important roles in maintaining skin health. For example, *C. acnes* produces propionic acid from glycerol, a hydrolysis product of skin triacylglycerols, with lipase secreted by skin microorganisms. The resulting propionic acid inhibits the growth of *S. aureus* (Fig. 3D). However, *C. acnes* has also been implicated in the pathogenesis of several diseases, such as acne vulgaris, a common inflammatory skin disease affecting 85% of teenagers and 11% of adults. Thus, *C. acnes* is an intermediate microorganism with respect to both skin health and diseases.

Recent studies have revealed that *C. acnes* clinical isolates can be classified into distinct phylotypes. There are at

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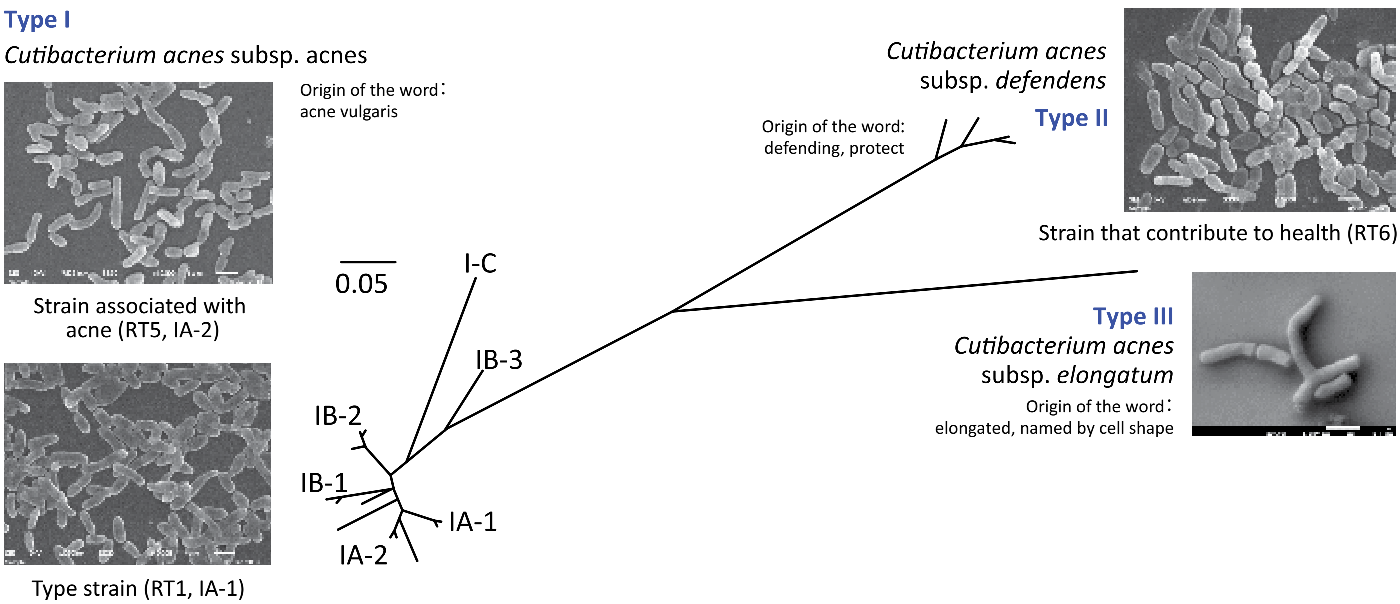

FIG.5. Phylogenetic tree and classification of *C. acnes* strains

least two methods for the classification of *C. acnes* strains: one based on a combination of genetic, phenotypic, and morphological differences (Types I–III) and another based on 16S ribotyping (RT1–6). The following re-classification with sub-species has been proposed: *C. acnes* subsp. *acnes* for Type I strains, *C. acnes* subsp. *defendens* for Type II strains, and *C. acnes* subsp. *elongatum* for Type III strains (Fig. 5) [3].

When *C. acnes* strains were classified by 16S ribotyping, strains in RT1–3 subgroups were evenly distributed among healthy individuals and patients with acne [4]. Strains in the RT4 and RT5 subgroups were found in patients with acne, and RT6 subgroup strains were found on healthy skin. These results imply that not all *C. acnes* strains are related to acne. Several key differences among strains have been identified. For example, RT4 and RT5 strains produce higher levels of porphyrins, compounds that generate reactive oxygen species and cause inflammation in keratinocytes, than those of other strains. Moreover, these strains induced increases in the secretion of the pro-inflammatory cytokines IFN-gamma and IL-17 by peripheral blood mononuclear cells, and the RT6 strain induced higher levels of anti-inflammatory IL-10 secretion.

We thus screened novel agents that selectively suppress the growth of the acne-associated RT4 and 5 strains, but not the harmless RT6 strain. Many common antibacterial reagents, such as salicylic acid, benzoyl peroxide, and isopropyl methyl phenol, show nearly equal minimum inhibitory concentrations (MIC) against the acne-associated RT4 and RT5 strains and the non-acne-associated RT6 strain. However, in an analysis of many saturated fatty acids, palmitoleic acid, and oleic acid, pentadecanoic acid (C15:0) acid showed good selective antibacterial activity; that is, it showed low MIC values against the acne-associated RT4 and RT5 strains and a high MIC value against the RT6 strain observed only on healthy controls [5]. These results suggest a new selective strategy for the treatment of acne.

FUTURE RESEARCH AND DEVELOPMENT

As a result of collaboration among three organizations, the cosmetic company (Momotani Juntenkan Ltd., Osaka, Japan) has commercialized a new cosmetic containing POA. However, the corresponding author's future goal is to expand on that by developing applications that incorporate POA into quasi drugs and medicines for AD treatment, as well as for improving rough hands. Thus, the recent commercialization will promote further research that will enable such products to be developed by many researchers from a wide range of fields. Furthermore, we hope that our studies inspire a rethink regarding the removal of *all* skin microorganisms as a pre-requisite to good health.

Toshihiro Nagao leads a lipid engineering laboratory at the Osaka Research Institute of Industrial Science and Technology (Osaka, Japan). His research focuses on functional lipids, lipases, and the skin microbiota. He can be contacted at nagao@omtri.or.jp.

Ayaka Uyama leads a next research and innovation laboratory at Momotani Juntenkan Ltd. (Osaka, Japan). Her company is a cosmetic manufacturer established in 1885, after the launch of Nikibitori Bigansui (which means acne-removing beautiful-face water in Japanese), a toner for acne problems. Her company is currently conducting intensive research on microbiota that contribute to beauty and health.

Teizo Sugino is a general manager of a next research and innovation laboratory at Momotani Juntenkan Ltd.

Shigemitsu Tanaka is a research scientist in a lipid engineering laboratory at the Osaka Research Institute of Industrial Science and Technology.

Noriaki Kishiomoto was formerly a professor of the Faculty of Agriculture, Kindai University (Nara, Japan).

Understanding pulse anti-nutrients

Mark Messina

Pulses have desirable health and nutritional attributes and their consumption may help mitigate climate change, but they are an underutilized source of nutrition in most developed countries despite recommendations by health agencies to increase their intake. This could be due in part to concerns about antinutrients.

- **Pulses have desirable health and nutritional attributes, but raw pulses contain relatively high levels of antinutrients.**
- **These compounds may reduce protein digestibility and the absorption of minerals or even have direct detrimental effects.**
- **Soaking and heating eliminates, reduces, or inactivates many of them.**
- **The health advantages of pulses greatly outweigh any residual antinutrient content in properly processed pulses.**

Antinutrients are classically defined as compounds that inhibit nutrient use, but the broader definition used in this article includes compounds that have direct detrimental effects independent of nutrient use. Many plant foods contain antinutrients. For example, cruciferous vegetables contain glucosinolates, which can inhibit thyroid function. Potatoes and tomatoes contain solanine, a glycoalkaloid poison that interacts with mitochondrial membranes. These types of compounds are ubiquitous throughout the plant kingdom and often serve as defense molecules or phytoalexins that enhance plant survival by warding off predators, and their concentration increases when plants are stressed. Antinutrients are not limited to plants; raw eggs contain avidin, which inhibits biotin absorption.

Such foods can be safely consumed, because conventional food processing (soaking, heating, milling, germination, and fermentation) greatly reduces their concentrations and/or because only consuming excessive amounts is harmful. Many antinutrients in plants are also under study for their potential health benefits. For example, glucosinates are widely touted for their chemopreventive properties. The isoflavones in soybeans are purported to exert several benefits in postmenopausal women, such as improving bone mineral density and alleviating hot flashes, and some antinutrients discussed in this article have proposed benefits as well.

The antinutrients in pulses include protease inhibitors, phytate, oxalate, lectins, tannins, saponins, polyphenols, amylase inhibitors, and oligosaccharides. This article focuses only on the first four and the two processes that are most applicable to pulses: soaking and heating. Also, while the soybean is not considered a pulse (pulses are the dried edible seeds of plants in the legume family, and soybeans are too high in fat to be dry), it has been extensively researched and is often used as a comparator.

PROTEASE INHIBITORS

Proteolytic enzymes, or proteases, catalyze the hydrolytic cleavage of specific peptide bonds in their target proteins. They are widespread in the plant kingdom and form less active or fully inactive complexes with their cognate enzymes. Protease inhibitors are induced in response to injury or attack by insects or pathogens. Protease inhibitors common in pulses include trypsin inhibitors, the Kunitz Trypsin Inhibitor, and the Bowman-Birk Inhibitor. Protease inhibitors can comprise as much as 6% of a legume's total protein content.

The extent to which their activity is destroyed by heat is a function of temperature, heating duration, particle size, and moisture conditions. Relatively little protease inhibitor remains in properly processed pulses. Soaking and cooking different beans at 95°C in water (1:5 seed:water) in a beaker for 1 h destroys 100% of the chymotrypsin inhibitor activity and 80 to 100% of the trypsin inhibitor activity, and a similar process

was shown to eliminate 100% of the trypsin inhibitor activity of Canadian and Egyptian cowpea, kidney beans, and pea.

PHYTATE

Phytate, or inositol hexaphosphate (IP6), is a naturally occurring compound found in whole grains and legumes. It is the major storage form of phosphorous, comprising 1–5 % by weight in cereals, legumes, oil seeds, and nuts. It represents 50–85 % of the total phosphorous in plants, and grains are the primary sources of phytate in Western diets.

Phytic acid is made up of an inositol ring with 6 phosphate ester groups. It is the most abundant form of myo-inositol phosphate found in mature, unprocessed plant-based foods. Phytic acid chelates cations, forming insoluble complexes with minerals in the upper gastrointestinal tract. These complexes cannot be digested or absorbed by humans because of the absence of intestinal phytase. However, during some food-processing and storage practices, IP6 is dephosphorylated to lower myo-inositol phosphate forms, some of which no longer inhibit mineral absorption. However, most of the phytate in beans is present as IP6 or IP5.

While moist heat at high temperature destroys most protease inhibitor activity, boiling beans only reduced phytate content by an average of about 20%. The reduction varies markedly among species. Boiling reduced about 50% of the phytate content from cowpea, pea, and kidney beans, and most of the loss was from soaking prior to heating.

Compared to heme iron, the non-heme iron found in plant foods is poorly absorbed due to iron absorption inhibitors, mostly phytate. Consequently, the Institute of Medicine of the National Academies set the iron recommended daily allowance (RDA) for vegetarians, who consume only nonheme iron, at 1.8 times the non-vegetarian RDA, and the European Food Safety Authority set zinc requirements based on four different levels of phytate intake (300, 600, 900, and 1,200 mg/d).

Iron absorption from single meals based on black beans, lentils, mung beans, and split beans was found to be very low, ranging from only 0.8% to 1.9%. However, since multiple plant components affect iron absorption, the contribution of phytate to the poor iron absorption of beans could not be determined. On the other hand, genetically reducing the phytate content of common beans by 90% leads to an approximate doubling of iron absorption.

Phytate also inhibits calcium absorption from legumes. The fractional calcium absorption from milk and high and low-phytate soybeans was found to be 0.377, 0.310, and 0.414, respectively. Zinc intake is also inhibited by phytate but to a lesser extent than iron.

Since most of the information about the impact of inhibitors on mineral absorption comes from single meal studies, Cook, *et al*. [1], concluded that "in the context of a varied Western diet, nonheme-iron bioavailability is less important than absorption studies with single meals would suggest." This may also be true for zinc.

Importantly, in contrast to an initial report by Brune, *et al*. [2], Armah, *et al*. [3], recently found that habitual consumption of a high-phytate diet minimizes its inhibitory effects. Differences in study design could explain the discrepancy: The average daily phytate intake in the more recent study was 1,190 mg, whereas the average intake in the initial work was only 323 per day, which is quite low. Whether this adaptation applies to other minerals inhibited by phytate has not been established.

Several researchers have argued that iron absorption from soybeans is greater than the data suggest because the traditional methodology used to assess iron absorption is not appropriate for measuring the bioavailability of iron in the form of ferritin, a form of iron that may be insensitive to iron inhibitors. The percentage of iron in the form of ferritin ranged from 10 to 41% among six legumes, but it is premature to reach any definitive conclusions about iron ferritin bioavailability. It is also worth noting that vegetarian iron stores are lower than iron stores of non-vegetarians, although the clinical significance of these lower stores, if any, is a matter of debate.

OXALATE

Oxalic acid and its salts occur as end products of metabolism in several plant tissues. Oxalic acid forms water-soluble salts with Na^+, K^+, NH_4^+ ions. It also binds with Ca^{2+}, Fe^{2+}, and Mg^{2+}, rendering these minerals unavailable for absorption. However, Zn^{2+} appears to be relatively unaffected, and although there is some evidence that oxalate inhibits iron absorption, not all data indicate this is the case. The primary concern from a nutrient standpoint is oxalate's impact on calcium absorption. Also, a high-fiber and high-oxalate diet worsens calcium balance compared to a high-fiber or high-oxalate diet alone.

It is well known that calcium absorption of high-oxalate vegetables is extremely poor. The absorption index (calcium absorption of test source divided by the milk calcium absorption value) of the high-oxalate vegetables Chinese spinach, rhubarb, and sweet potatoes was 0.257, 0.235, and 0.423, respectively, whereas from the low-oxalate vegetables Chinese mustard greens and Chinese cabbage flower leaves, it was 1.080 and 1.097, respectively [4].

The authors of this study concluded that the likely explanation for the phytase-resistant calcium absorbability deficit of pinto beans—fractional calcium absorption from pinto beans to which phytase was added was still lower than from milk (Fig. 1)—was due to the oxalate content. Interestingly, despite its high oxalate and phytate content, the absorption of calcium from soybeans and calcium-fortified soymilk and calcium-set tofu is comparable to or only slightly lower than from cow's milk.

The risk of developing kidney stones is an additional concern with high-oxalate foods. The incidence and prevalence of kidney stones is increasing in much of the world. In the United States, the prevalence of kidney stones increased from 3.2% in 1976 to 1980 to 5.2% in 1988 to 1994. According to the most recent estimate from the National Health and Nutrition Examination Survey (2007–2010), the prevalence of kidney stones is 8.8% (10.6% among men, 7.6% among women).

Approximately 80% of the kidney stones in industrialized countries are composed of calcium salts—usually calcium oxalate and, to a lesser extent, calcium phosphate. Urinary oxalate is the single strongest chemical promoter of kidney stone formation, as it has a much bigger effect on stone formation than urinary calcium. As much as 50% of the oxalate in the urine comes from food when a typical diet containing 10–250 mg dietary oxalate is consumed; the other half comes from endogenous synthesis.

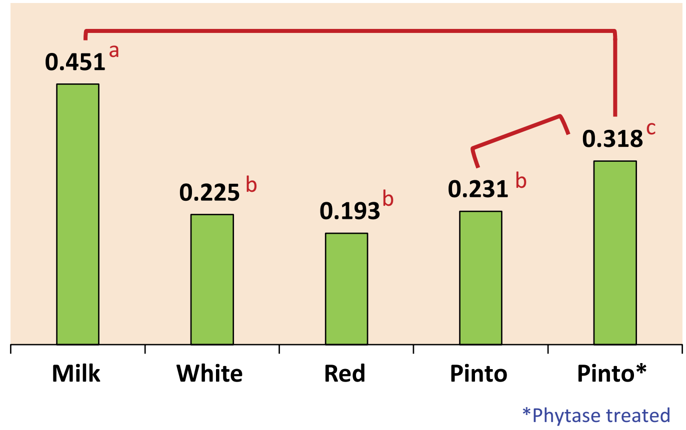

FIG. 1. Fractional calcium absorption from white, red, and pinto beans. When phytase was added to the pinto beans, absorption increased.

The American Dietetic Association classifies foods containing >10 mg oxalate per serving to be high-oxalate foods and recommends that kidney stone formers limit their intake. Further, it is recommended, especially for individuals who are hyperabsorbers of oxalate, to limit total oxalate intake to no more than 100 mg per day. In fact, Han, *et al*. [5], recently recommended consuming no more than 40–50 mg oxalate per day to prevent recurrence of kidney stones. Several studies indicate that stone formers on average may absorb about 50% more oxalate than healthy individuals.

Compared to high-oxalate foods such as Red Swiss chard, spinach, and rhubarb, which contain about 1,000 mg per 100 g *wet* weight, the oxalate content of soaked and cooked legumes is low, ranging from about 60 to 180 mg/100 g *dry* weight (approximately 20 to 60 mg wet weight). Consuming many pulses would still not be recommended for those at risk of developing or who have a history of kidney stones. However, Chai, *et al*. [6], reported that cooked garbanzo beans, mung beans, lentils, large lima beans, green split peas, yellow split peas, and blackeye peas each contained no more than 10 mg per 100 g wet weight. So, these foods would be acceptable.

Boiling vegetables decreased total oxalate content 30% to 87%, primarily by loss of soluble oxalate (Table 1). In spinach and carrots, the decrease in total oxalate corresponded to the amount of oxalate found in the cooking water. Similar results were found when New Zealand and Thai vegetables were boiled, so boiling vegetables may be an option to reduce soluble oxalate, if the cooking water is not consumed. In contrast, baking potatoes or roasting peanuts or sesame seeds does not reduce oxalate. For many legumes, cooking reduced oxalate content by 31 to 66%, most of which occurred as a result of soaking.

The relative amount of soluble and insoluble oxalate is an important consideration. Insoluble oxalate is bound to another molecule such as calcium or magnesium, which makes it difficult to absorb. Taking calcium supplements with a meal to bind oxalate and prevent its absorption is sometimes recommended for kidney stone patients. Soluble oxalate is not attached to another molecule, so is more easily absorbed.

TABLE 1. Oxalate content (mg/100 g wet weight) of cooked legumes (boiled and drained)

Legume	mg	Legume	mg
Anasazi	80	Azuki	25
Small white	78	R. kidney	16
G. Northern	75	Garbanzo	9
Pink	75	Mung	8
Black	72	Lentils	8
Navy	57	Large lima	8
Soy	56	Green split	6
Small red	35	Yellow split	5
October	28	Blackeye	4
Pinto	27		

The relative amount of each form in foods varies markedly. For example, the ratio of soluble to insoluble oxalate in wheat bran, oat bran, barley bran, red kidney beans, and white beans was 0.38, 0.99, 0.81, 0.21, and 0, respectively.

Since solubility affects absorption, foods with higher amounts of soluble oxalate lead to higher urinary oxalate levels. To illustrate, cinnamon (3.5 g) and turmeric (3.2 g) each provide 63 mg oxalate, but approximately 91% of the oxalate in turmeric and 6% in cinnamon is soluble. Consequently, turmeric consumption significantly increases urinary oxalate levels in patients with a history of kidney stones, whereas cinnamon has no effect. Similarly, 37 mg of the 120 mg oxalate in almonds was determined to be soluble, whereas only 6 of 100 mg in black beans was. Among 6 male and 5 female study participants, 5.9% and 1.8% of the oxalate in almonds and black beans was absorbed, respectively. Not surprisingly, the authors concluded that for individuals with hyperoxaluria or who are prone to forming oxalate-containing kidney stones, eating almonds was riskier than eating beans.

Many factors besides oxalate intake affect kidney stone formation. Increasing water intake, decreasing animal protein, limiting sodium, and increasing fruit and vegetable consumption are often recommended for prevention. These other risk factors may account for why a preliminary British survey found that vegetarians were only half as likely to develop kidney stones as non-vegetarians.

Recent data also show that adhering to the DASH (Dietary Approaches to Stop Hypertension) diet is very protective against renal stones. Interestingly, phytate strongly inhibits calcium oxalate crystal formation *in vitro*. This may be why an analysis from the Nurses' Health Study II, which included 96,245 female participants, found that over an 8-year follow up period, phytate intake was associated with a 63% reduced risk of stone formation.

LECTINS

Beans are the main source of dietary lectins, but these carbohydrate-binding proteins are widely distributed throughout the plant kingdom. More than 500 lectins have been identified. The lectin ricin was isolated from castor beans (*Ricinus communis* L.) in the late 1800s. The lectin in soybeans was discovered in the 1950s.

In plants, lectins function as nitrogen storage compounds but also have a defensive role, protecting plants against pests and predators and possibly mediating specificity in Rhizobium-legume symbiosis. Lectins are capable of specific recognition of and binding to carbohydrate ligands.

The term "lectin" is broadly used to denote "all plant proteins possessing at least one non-catalytic domain, which binds reversibly to a specific mono- or oligosaccharide."

Undigested plant lectins remaining in the gut may bind to a wide variety of cell membranes and glycoconjugates of the

Want full references?

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Mark Messina was also a presenter at the inaugural Pulse Science and Technology Forum held in November 2019.

Presentation slides from the conference on many topics related to pulses are available at aocs.org.

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intestinal and colonic mucosa, leading to deleterious effects on the mucosa as well as on the intestinal bacterial flora and other inner organs. The severity of these adverse effects may depend upon the gut region to which the lectin binds.

High resistance to proteolytic degradation results in nutritionally significant amounts of intact and highly reactive forms of certain dietary lectins within the gut lumen. Intact peanut agglutinin (PNA) can be detected at up to 5 mg/ml in the systemic circulation after eating peanuts, enough to stimulate proliferation of epithelial cells. Detection with a heme agglutination assay implies retained biological activity.

Several cases and outbreaks of lectin poisoning from consumption of raw or improperly processed kidney beans have been reported. A dose of purified ricin powder the size of a few grains of table salt can kill an adult human. Because lectin proteins bind to cells for long periods of time, they can potentially cause an autoimmune response and are theorized to play a role in inflammatory conditions like rheumatoid arthritis and type 1 diabetes.

Lectins also bind to carbohydrates in ingested food, and limit or change their potential hydrolysis and absorption from the gut. Thus, they reduce the amount of energy for growth and maintenance. They can also increase proliferation of pathogenic bacteria in the gut and increase intestinal permeability.

There is a large variation in the lectin content of different varieties of raw legumes. The lectin content of soybean varieties varies as much as fivefold. The most practical, effective, and commonly used method to abolish lectin activity is aqueous heat treatment. The lectin activity in fully hydrated soybeans, kidney beans, faba beans, and lupin seeds was completely eliminated under conditions where the seeds are first fully soaked in water and then heated in water at or close to 100°C. A more recent study showed that soaking and cooking beans eliminated most, but not all, of the lectin activity. Boiling at 95°C for 1 hour eliminated ~97% of the activity in different varieties of peas and lentils, >99% in different varieties of beans, 99% in two varieties of fava bean, and >99% in soybeans.

Given that exposure to lectins is widespread, an editorial in the *British Journal of Medicine* 20 years ago asked, "Why don't we all get insulin-dependent diabetes, rheumatoid arthritis, IgA nephropathy, and peptic ulcers [7]?" The answer was, "partly because of biological variation in the glycoconjugates that coat our cells and partly because these are protected behind a fine screen of sialic acid molecules, attached to the glycoprotein tips." Clinical evidence that any residual lectin activity in properly prepared pulses (soaking and boiling) leads to detrimental effects is lacking.

Mark Messina, PhD, is the executive director of the Soy Nutrition Institute, president of Nutrition Matters, Inc., a nutrition consulting company, and is an adjunct associate professor at Loma Linda University (California, USA). He has spent the past 30 years focusing primarily on the health effects of soybeans and consumes legumes daily. He can be contacted at markjohnmessina@gmail.com.

AOCS MEETING WATCH

April 26–29, 2020. AOCS Annual Meeting & Expo, Palais des congrès de Montréal, Montréal, Québec, Canada.

May 2–5, 2021. AOCS Annual Meeting & Expo, Oregon Convention Center, Portland, Oregon, USA.

May 1–4, 2022. AOCS Annual Meeting & Expo, Hyatt Regency Atlanta, Atlanta, Georgia, USA.

November 17–19, 2020. Fabric and Home Care World Conference, Jing An Shangri-La Hotel, Shanghai, China

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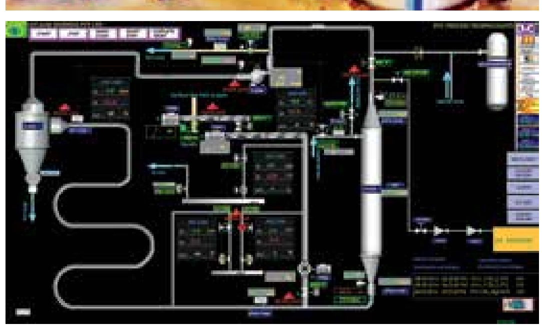


"Insects for Africa": opportunities for insect production in East Africa

Teun Veldkamp and Adriaan Vernooij

- The demand for animal protein for human consumption is growing worldwide, and so is the demand for ingredients to produce animal feed. Traditional animal feed ingredients are either getting in short supply or have increasing negative environmental consequences.

- Insects are considered a suitable and environmentally friendly alternative. Many countries, such as Kenya, largely depend on imports of raw material for animal feed production and are eagerly looking for alternatives that can be produced locally.

- A quick scan by Wageningen University (the Netherlands) detected a high level of interest in insects from the feed industry in Kenya, as well as growing enthusiasm among local insect producers to provide insects for animal feed. There is, however, a clear need for further professionalization of insect production systems there.

Wageningen University & Research in the Netherlands has been conducting research on the use of insects as food and feed for almost two decades. As a result, the small rural town of Wageningen has been nicknamed the "City of Insects," and the University has developed broad experience ranging from entomology, to consumer acceptance of insects as food ingredients, to the use of insect meal as a protein source in animal feed.

The demand for animal protein is growing strongly worldwide, and in eastern Africa (Kenya, Tanzania, and Uganda). Kenya is leading the production of animal feed in the region, with an annual production of compound animal feed that approaches 1 million metric tons (MMT). Uganda produces more than 300,000 MMT annually, and Tanzania close to 100,000 MMT.

INTERVIEWS AND FIELD VISITS

To assess options for transferring knowledge and skills used in the production and use of insects for animal feed to developing countries, a study was carried out to determine the feasibility of producing insects for feed in East Africa. In 2018, two researchers visited Kenya to inventory the growing demand for animal feed and to analyze the potential role of insect production as a future ingredient for animal feed.

As part of that study, interviews were held with stakeholders on the demand-side, such as large feed companies, livestock producers interested in using insects as feed ingredients, and the current producers of insects in the country.

While all stakeholders involved realize that insects could potentially play an important role in supplying protein ingredients, local experience with insect production for animal feed is limited. Several small-scale efforts are ongoing to support insect production or use at individual farms or at the village level, with support from the International Centre for Insect Physiology and Ecology in Kenya (ICIPE). Additionally, a handful of medium-sized insect producers are currently active in the country, but they are only capable of supplying small-scale feed mills. The larger feed mills require much bigger volumes of consistent quantity and quality, and this is not yet available in Kenya or other African countries.

Insects could potentially replace other more common sources of protein that are currently imported into Kenya for animal feed, such as soybean meal, sunflower seed meal, cottonseed meal, and fish meal. Silver cyprinid fish (omena) is often used as fishmeal in Eastern Africa. The market demand for silver cyprinid fish and soybean is high, but available quantities are way below the demand, requiring importation. Furthermore, the quality of omena fishmeal is sub-optimal and varies with the drying process of the fish. Quite often a lot of sand is included in the fish, resulting in ash contents that occasionally exceed 15%. Feed manufacturers must then separate the sand from the fish, which results in additional costs for labor and sand disposal. Replacing 25% of the protein in poultry feed alone in Kenya would require 27,000 to 32,000 tons of dried insects/year.

FUTURE PROSPECTS: OPTIONS AND CHALLENGES

Substituting 100% of the conventional proteins in feed for laying and broiling hens with Black Soldier Fly (BSF) would boost the demand for insects in Kenya to 115,000 tons of dried insect annually. Add to that the increased demand from the fish, poultry, and pig industries, and insect production for animal feed has a brilliant future. It is estimated that substituting conventional proteins with insects could reduce protein costs for feed production by 25 to 37.5% in the short term, and possibly by more than 50% in the medium and long term.

Meeting the growing demand for insect meal will require production improvements at all insect-producing facilities that are currently operating in Kenya. Additional management advice is needed at many insect-producing units, and more research is needed to determine the most efficient and available substrates for raising insects, how to achieve climate control in production rooms, and which type of insects are most suited to Kenyan circumstances (Fig 1).

Meanwhile, the country's regulatory environment is very conducive to using insects in animal feed. New regulations were introduced in early 2018, when the Kenya Bureau of Standards approved new rules that specify the requirements for dried insect products as sources of protein for compound animal feed.

Insect production in Uganda has mainly been small-scale and largely focused on the use of insects as ingredients for human food only. There is very little experience on insect growing in Tanzania, apart from a project linked to urban waste recycling in Dar es Salaam.

FIG. 1. Cleaning black soldier fly larvae

FUTURE OUTLOOK

Due to Kenya's dependency on imports of raw material for feed, there is a strong interest in insects as an alternative protein source for animal feed in aquaculture, poultry, and pig production, even on the part of the larger feed-producing companies. However, adequate volumes of consistent quantity and quality, cannot be met by current production levels or conditions at production facilities.

Advancing insect production will require a readily available and cost-effective source of food for the insects that are raised in Kenya and the region. Insects can be fed on various types of waste, but the composition of the waste has a strong effect on the growth and chemical composition of the larvae (Fig. 2, page 26).

FIG. 2. Reproduction units

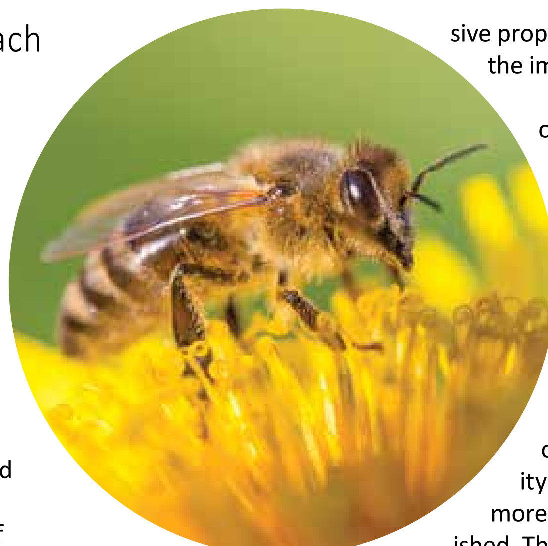
With experience from companies producing insects elsewhere in the world and adaptation of existing technology to East African standards, insect production could easily become a serious business in the Eastern African region. For more details, please see the full report, “Insects for Africa: developing business opportunities for insects in Animal feed in Eastern Africa,” at https://library.wur.nl/WebQuery/wurpubs/fulltext/470617.

Teun Veldkamp is an animal nutrition researcher in Wageningen Livestock Research, where he specializes in using insects as ingredients for animal feed. He has extensive experience in feeding insects to poultry and pigs in the Netherlands and other European countries, and is the President of the Insect Study Commission of the European Federation of Animal Science.

Adriaan Vernooij, also a researcher in Wageningen Livestock Research, is involved in the management of various international R&D projects with a special interest in feed for the future. He studies interdependence between countries on issues of livestock value chain development, including requirements for feed ingredients and the options for alternative sources such as insects.

Adhesive formed from bee spit and flower oil could form basis of new glues

Honey bees spend hours each day collecting pollen and packing it into tidy bundles attached to their hind legs (see video: http://tinyurl.com/yyrvck7f).



But all of that hard work could instantly be undone during a sudden rainstorm were it not for two substances the insect uses to keep the pollen firmly stuck in place: bee spit and flower oil.

Researchers at Georgia Institute of Technology are looking at that mixture of ingredients as a model for a bio-inspired glue because of its unique adhesive properties and ability to remain sticky through a range of conditions.

"A bee encounters not just wet and humid environments but windy and dry surroundings as well, so its pollen pellet must counteract those variations in humidity while remaining adhered," said J. Carson Meredith, a professor in Georgia Tech's School of Chemical and Biomolecular Engineering. "Being able to withstand those kinds of changes in humidity is still a challenge for synthetic adhesives."

In a study published in the journal *Nature Communications* (https://doi.org/10.1038/s41467-019-09372-x) and sponsored by the Air Force Office of Scientific Research, the researchers described how those two natural liquids work together to protect the bee's bounty as it travels back to its hive.

The first component of the glue is the bee's own salivary secretions, which coat the pollen grains and allow them to stick together. The bees produce those sugary secretions, the main ingredient in honey, from nectar they drink from the flowers.

The second ingredient is a plant-based oil that coats the pollen grains called pollenkitt, which helps stabilize the adhesive properties of the nectar and protect it from the impact of too much or too little humidity.

"It works similarly to a layer of cooking oil covering a pool of syrup," Meredith said. "The oil separates the syrup from the air and slows down drying considerably."

The researchers tested the adhesive properties of the bee's glue by separating the oil-based component from the sugar-based component and evaluating how sticky the nectar remained under various humidity conditions. As expected, as humidity increased and the nectar absorbed more water, its adhesive properties diminished. The same effect was true when humidity decreased and the nectar dried out. Meanwhile, under similar conditions, nectar coated with the pollenkitt oil remained sticky despite changes in humidity.

"We believe you could take the essential concepts of this material and develop a novel adhesive with a water-barrier external oil layer that could better resist humidity changes in the same way," Meredith said. "Or potentially this concept would apply to controlling the working time of an adhesive, such as its ability to flow and time to dry or cure."

The research team, which included Victor Breedveld, an associate professor in the School of Chemical and Biomolecular Engineering, also examined dynamics of the bee adhesive.

"We wanted to know, if the pollen can stay so firmly attached to the bee's hind legs, how do the bees manage to remove it when they return to the hive," Meredith said.

The answer may lie in the adhesive's a rate-sensitive response. In other words, the faster the force attempting to remove it, the more it would resist.

"This is a property of capillary adhesion, which we believe could be harnessed and tailored for specific applications, such as controlling motion in microscopic or nanoscale devices, in fields ranging from construction to medicine," Meredith said.

4-hydroxy-2-hexenal and 4-hydroxy-2-nonenal in vegetable oil: potential health concern

Guoqin Liu and Lukai Ma

- Vegetable oils, which are consumed worldwide, have high contents of unsaturated fatty acids (UFA).
- While UFA are generally considered healthful, their susceptibility to peroxidation has raised some health concerns.
- Two toxic nonvolatile aldehydes, 4-hydroxy-2-hexenal (HHE) and 4-hydroxy-2-nonenal (HNE), which are closely related to the oxidation of omega-3 and omega-6 polyunsaturated fatty acids, respectively, have drawn increasing attention.
- HHE and HNE have been found in many commercial vegetable oils, especially those that have undergone thermal processing. Both compounds are readily incorporated into fried food and become a part of our daily meal.

Vegetable oils not only provide us with energy, but also with essential fatty acids—especially unsaturated fatty acids (UFA) such as oleic acid (omega-9), linoleic acid (omega-6), and linolenic acid (omega-3). They are also a leading source of fat-soluble vitamins. Thus, any issues related to the safety of vegetable oils are vitally important.

Due to their high content of unsaturated fatty acids—especially polyunsaturated fatty acid (PUFA)— vegetable oils are prone to oxidation, generating primary and secondary oxidation products. Among the various oxidation products, special attention has been paid to the typical hydroxylated alpha,beta-unsaturated aldehydes, 4-hydroxy-2-nonenal (HNE), and 4-hydroxy-2-hexenal (HHE). Both HHE and HNE (Fig. 1) possess C=O, C=C, and a hydroxyl group, which can conduct two types of reactions: Michael addition and Schiff base formation.

HHE and HNE arise specifically from the degradation of omega-3 and omega-6 fatty PUFA, respectively. They have been shown to be highly reactive toward biomacromolecules, such as protein, DNA, and phospholipid, leading to damage

Guoqin Liu presented this topic and co-chaired the Analytics and Quality Technical Session at the AOCS China Section Conference: Health, Advanced Processing and Value-Added Utilization, in Guangzhou, China, November 8–10, 2019.

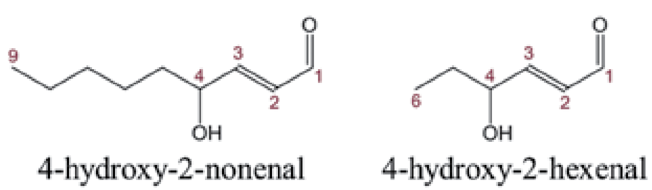


FIG. 1. Structure of 4-hydroxy-2-nonenal and 4-hydroxy-2-hexenal

and structure-associated functionality. A growing body of evidence indicates that HHE and HNE are involved in the onset and propagation of several human diseases, including but not limited to atherosclerosis, diabetes, and cancer. HNE has drawn specific attention since it was discovered to be highly reactive and toxic by Esterbauer Hermann, who is known as "the father of HNE." Compared to HNE, HHE is "the step-child in the 4-hydroxyalkenen family." Although the toxicity of the HHE had been recognized to be almost the same as that of HNE, research about HHE is still scare. It was not until HHE was detected in infant formulas that it attracted the interest of the food science and oil chemistry community.

Unfortunately, these two toxic aldehydes have been found in various edible oils and oil-based foods (Fig. 2). Although the contents of HNE and HHE found in fresh commercial vegetable oil, such as palm oil, are relatively low—at levels ranging from 0.03 ~ 0.08 microgram/g oil for HHE, and 0.00 ~ 0.08 microgram/g oil for HNE—high contents of HHE and HNE are detected in vegetable oils during laboratory tests that mimic

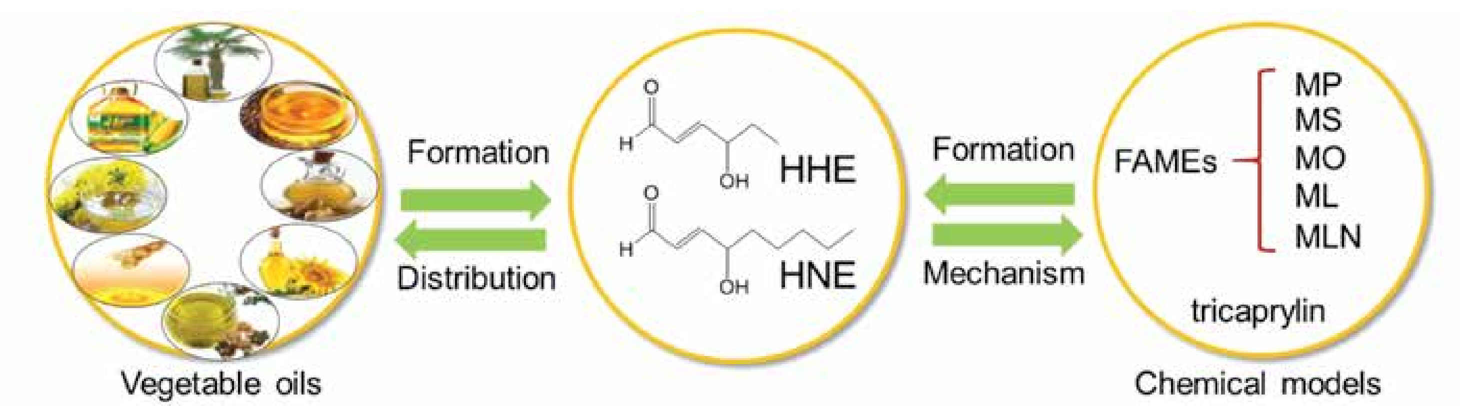


FIG. 2. Distribution of HHE and HNE in various vegetable oils and the formation mechanism

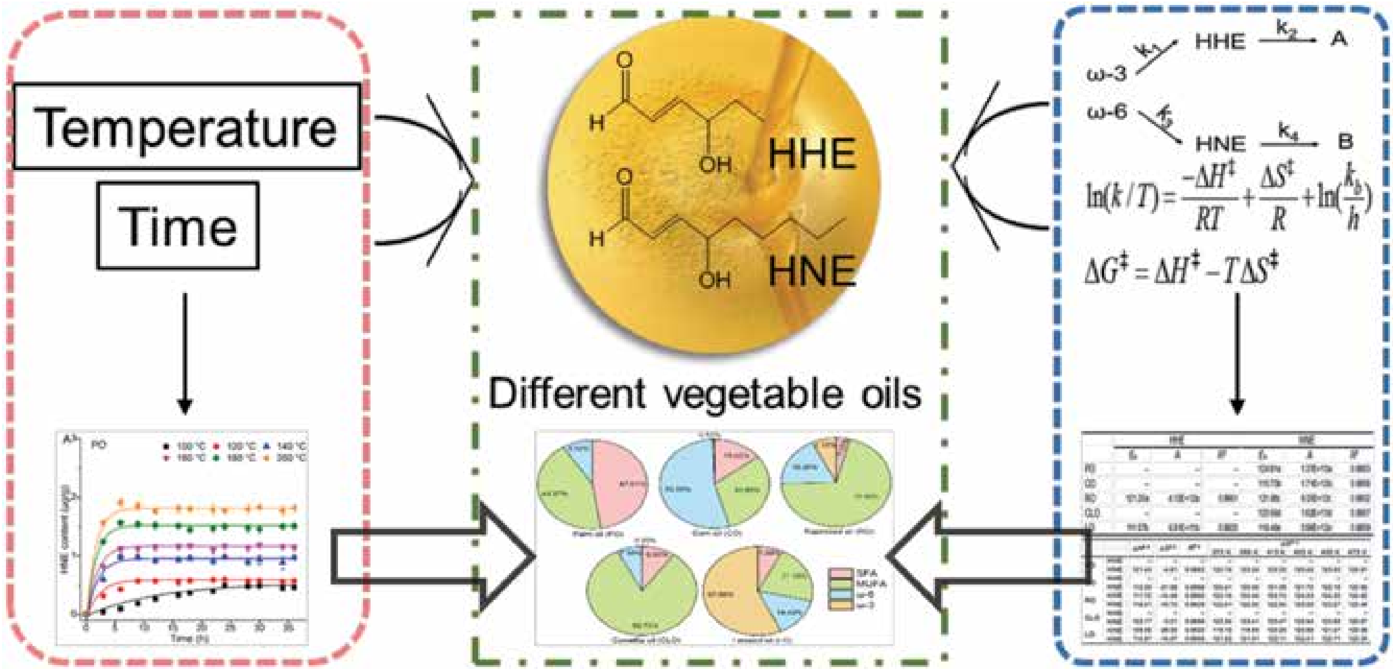


FIG. 3 Formation kinetics of HHE and HNE during thermal processing (100–200°C)

storage. For example, the content of HHE and HNE in oils subjected to the Schaal oven test can be as high as about 4.5 microgram/g oil in linseed oil and 3.7 microgram/g oil in corn oil. In addition, the formation of HHE and HNE was found to be closely related to the initial PUFA content in the oil sample. Given that HHE and HNE originate from the oxidation of omega-3 and omega-6 fatty acids, respectively, these two aldehydes could be used as indicators of PUFA degradation in vegetable oils, and also as indicators of oxidation in oil samples.

Like the formation of other contaminants during vegetable oil processing, the formation of HHE and HNE in vegetable oil is affected by many factors (Fig. 3). First, HHE and HNE formation is temperature dependent and rises significantly with increasing temperature. After heating corn oil at 120°C for 5h, the HNE content was approximately 2.0 microgram/g oil, while the HNE content in corn oil heated at 200°C for the same period of time was 6.0 microgram/g oil.

Second, heating time also affected the formation of HHE and HNE. The content of both compounds increased quickly with the duration heating time before reaching equilibrium, Last, but not least importantly, HHE and HNE formation was influenced by the oil fractions. As demonstrated, saturated fatty acid and monounsaturated fatty acid produced no HHE or HNE, but they might promote formation of these compounds to some extent due to free radical transfer mechanisms during oxidation. Furthermore, the precursors of HHE or HNE could promote formation of other aldehydes. The peroxidation of methyl linolenate produced no HNE, but it could facilitate the formation of HNE significantly, whereas the promotion effect of methyl linoleate on the formation of HHE was weaker, mainly because of the stronger oxidizability of methyl linolenate. Both HHE and HNE were detected in various fried foods, including French fries and fried chicken legs. Their content in such foods could be as high as 5.24 ~ 5.96 microgram/g oil.

Given the significant levels of HNE and HHE that have been detected in various vegetable oils and fried foods, there is an urgent need to investigate their distribution in various edible oils and oil-based foods. Meanwhile, strategies to mitigate their formation should be implemented, and further studies conducted to provide detailed toxic data that can contribute to the regulation of these compounds in vegetable oils and oil-based foods.

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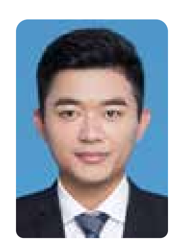
Lukai Ma is an associate professor in the College of Light Industry and Food, Zhongkai University of Agriculture and Engineering, Guangzhou, China, where his research is mainly focused on the safety and nutrition of vegetable oils. He can be contacted at m1991lk@163.com.



Are vaping liquids causing a deadly lung disease?

Olio is an Inform *column that highlights research, issues, trends, and technologies of interest to the oils and fats community.*

Rebecca Guenard

E-cigarettes pose a health crisis in the United States, where dozens of people have died and hundreds more have fallen ill (https://tinyurl.com/y2yrb5bc). Touted as a healthier alternative to tobacco, e-cigarettes vaporize liquid nicotine instead of burning tobacco, which forms carcinogenic compounds, like amines and benzenes, during combustion. The active ingredient in a vaping cartridge is dissolved in solvents like propylene glycol, vegetable glycerin, and vitamin E acetate (in certain vaping liquids). Flavor additives are also included in the liquid. All these compounds have been determined safe for use in food or on skin, but little is known about the effects on the lungs when vaporized and inhaled. Now, researchers are scrambling to determine if these ingredients are the source of a severe pulmonary disease plaguing e-cigarette users.

"Researchers across the country are trying to get protocols together as fast as we can and get the support we need to start studying healthy e-cigarette users' lungs," says Thomas Eissenberg, psychology professor and co-director of Virginia Commonwealth University's Center for the Study of Tobacco Products in Richmond, Virginia. "Right now, all we have seen is diseased e-cigarette users' lungs, so we only know the end result. We do not know what is going on before the disease progresses to a dangerous state. We need more data."

According to Eissenberg, when e-cigarettes first hit the market, regulatory concern focused on nicotine concentration. The European Union, in particular, was worried that if the device administered a higher dose of nicotine than a combustible cigarette, more people would suffer addiction. In 2013, they initially considered regulating e-cigarettes as a drug, a mandate that would require that the device be sold only in pharmacies. When the ruling was finally implemented in April the following year, this stricter oversight was lifted (https://tinyurl.com/y5vdz846). Instead, the EU chose to regulate e-cigarettes the same as tobacco. That meant they could not be advertised. They also had to be labeled with graphic warnings of their negative health effects, and e-cigarette liquid nicotine concentrations could not exceed 20 mg per mL (the nicotine limit of combustible tobacco).

To Eissenberg, these concerns seem misplaced, since early devices administered almost no nicotine. "They were as effective as an unlit cigarette at delivering nicotine," he says. Besides, device manufacturers or users could ramp up the power output of the e-cigarette and vaporize more nicotine despite its restricted concentration. Most critically, all the attention on nicotine detracted from starting investigations into the unknown potential hazards that hid in vaping liquids. A study published at the height of a deadly lung disease outbreak in the fall of 2019, is one of several indicators that the compounds may be doing significant harm (https://doi.org/10.1172/JCI128531). A research team found unusual formations in the lungs of mice exposed to e-cigarette aerosol.

"We isolated cells from the lungs of mice to determine why they looked odd," says Farrah Kheradmand, pulmonologist at Baylor College of Medicine in Houston, Texas, and one of the principle investigators for the study. They found that the cells were not dying as they had presumed. "These cells were just sitting there looking fat, figuratively."

For four months, mice inhaled either air, traditional tobacco smoke, vaping liquid containing a 60 percent propylene glycol (PG) to 40 vegetable glycerin (VG) mixture, or the PG/VG mixture with 33 mg per mL of nicotine. Researchers then examined whether exposure to e-cigarettes caused inflammation, and how it changed the cellular function of immune cells in the lungs. Unlike with exposure to traditional tobacco cigarettes, the mice did not display any type of airway inflammation that leads to emphysema. Without the carbon black deposits from tobacco combustion, the e-cigarette-exposed lungs showed no tissue damage. Instead, the researchers observed that immune response cells, known as macrophages, were swollen with lipids (Fig. 1).

"Initially we looked for glycerin," says Kheradmand, the assumption being that the PG/VG from the vaping liquid was directly absorbed by the cells. "We tested the contents within the cells, but there was no increased glycerin. So next we asked, 'Where was this fat coming from?'"

By examining other lung tissues, the researchers eliminated the probability of lipid synthesis in the cells through the dehydration of glycerin. They found that the abnormality from e-cigarette exposure was located in the lamellar bodies. In the lungs, lamellar bodies contain pulmonary surfactants. The surfactant is primarily composed of lipids with four different proteins mixed in that serve various functions (from lowering surface tension in the air sacs so the lung can inflate after exhalation to assisting in the destruction of pathogens that invade the lungs). Under normal conditions, macrophages and airway cells in the lungs routinely recycle this pulmonary surfactant.

Kheradmand and her team did a thorough examination of every aspect of pulmonary surfactant production and determined that the vaping liquids disrupt the recycling of this vital biological substance. Detecting a problem, the body speeds up phospholipid production to compensate, but the transport molecules responsible for maintaining balance cannot keep up, and macrophages start tucking the lipids away. Within only two weeks of exposure to vaping liquid, the immune mechanism within mouse lungs is so off kilter that macrophages begin showing signs of excess lipid storage.

"Our findings are consistent with abnormal surfactant turnover, abnormal surfactant biology, and abnormal innate immune response to viruses," says Kheradmand. Eissenberg explains that most likely vaping liquids induce a low-level, asymptomatic response. In other words, chronically occupied with repairing a damaged surfactant, the lungs of vapors do not have the capacity to fight off a virus and succumb to illness.

Kheradmand and Eissenberg both make it clear that these findings are preliminary. Controlled mouse studies hint at what could be happening in humans, but they are not definitive. More studies are needed on humans within the growing population of people who choose to vape, a population that continues to grow, particularly among teens.

As the EU finalized its restrictions, the US Food and Drug Administration (FDA) considered their own. After a three-year lag, the FDA issued a ruling in 2016. Despite urging from medical professionals, the ruling did not restrict the use of flavors in vaping liquids. Sales of candy- and treats-imbued vaping liquid cartridges continued, leading many policy makers to believe that the unchecked use of flavors like, sweet tart, cotton candy, and crème brûlée sent the number of young vapers soaring (Fig. 2). Between 2017 and 2018, vaping among middle and high school students rose from 3.6 million to 4.9 million, according to the US Centers for Disease Control and Prevention.

Past concerns about flavorings indicate that more research is needed on the compounds added to vaping liquids. In 2016, the US Department of Health and Human Services set a standard for diacetyl (a buttered popcorn-flavored compound) exposure in microwave popcorn factories after workers contracted a severe lung disease from inhaling its vapors. According to Kheradmand's article, there are over 7,000 vaping flavors currently on the market. "We just do not know the effects all these food flavorings will have on the lungs when they are heated and inhaled," says Eissenberg

It is undeniable that the flavors make the devices more enticing, according to Eissenberg. "I suspect that the reason the e-cigarette industry is so keen to keep flavors is because flavors help them retain customers." But he cautions against a

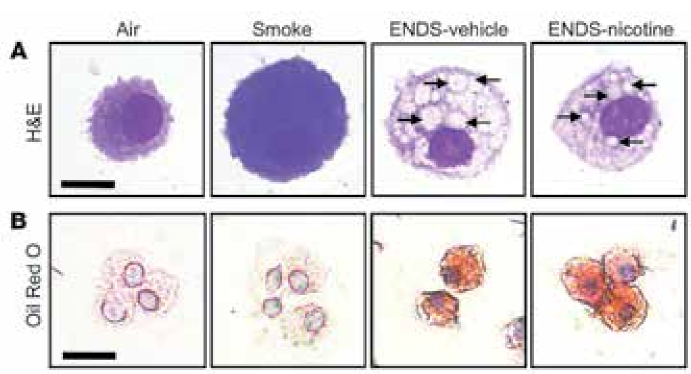


FIG. 1. Alveolar macrophages of mice exposed to air, smoke, and electronic nicotine delivery systems (ENDS) or e-cigarettes for 4 months. (A)Black arrows point to inclusions in the cells of e-cigarette-exposed mice. (B)Oil Red O staining reveals that the inclusions contain lipids. Source: Madison, *et al.*, *JCI 129*: 10, 2019.

FIG. 2. The FDA is concerned that the candy flavors of some e-cigarette liquids are encouraging more adolescents to get hooked on nicotine.

regulatory ban. Such a prohibition could drive flavored e-cigarette users toward bootleg vaping liquids, or worse, vapors could attempt to make their own recipes at home from store-bought ingredients. “That would be much more dangerous than if we tightly regulated flavors and had them sold at licensed vendors,” he says. Yet another aspect of e-cigarette liquids makes them more dangerous for casual users.

In 2018, scientists at Portland State University published a study showing that the chemistry of some vaping liquids could make them more addictive (https://doi.org/10.1021/acs.chemrestox.8b00097). They determined that e-cigarette manufacturer Juul formulates their nicotine cartages with the smoother, protonated form of nicotine instead of the free-base form which is well-known for burning the throat. “Juul has 68 mg per ml protonated nicotine liquid,” says Eissenberg, whose colleagues have tested the product. “You are able to inhale that much nicotine because the protonated form is much smoother on the throat.” Many experts are concerned that Juul’s selective chemistry and variety of flavors entice more people to get hooked on vaping. Juul states that its goal is to help people stop smoking tobacco (https://tinyurl.com/y473graz).

With vaping-related deaths on the rise, vaping research is racing against the clock. Kheradmand says she would like to repeat her experiments with vitamin E acetate, the solvent used with THC containing vaping liquids. Many victims of the lung disease outbreak report vaping THC, the active ingredient in marijuana, regularly. On November 8, 2019, the CDC reported that fluid taken from the lungs of 29 patients from across the United States contained vitamin E acetate. “Finding vitamin E acetate in the lungs does not prove causality,” says Kheradmand. In almost all cases people who developed the lung disease had used other vaping products. “As we have seen, this inhalation of toxicants can have deadly consequences,” says Eissenberg. “Numerous studies using a variety of methods suggest that electronic cigarette aerosols can be toxic to the lung, even when they are not contaminated with Vitamin E.”

Kheradmand says we are far from knowing the what, how, and why of this vaping-related lung disease. Her experiments require vapor exposure for four months followed by analysis time, so results are not imminent. Eissenberg is anxious to see if data from humans show a similar immune response to what is seen in mice. “People are really trying hard to learn what is going on as soon as we can,” says Eissenberg. He speculates that by sometime this year they will know what is causing the lung disease. As of press time, the CDC recommendation is that people stop all types of vaping.

Rebecca Guenard is the associate editor of Inform *at AOCS. She can be contacted at rebecca.guenard@aocs.org.*

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Safety evaluation of the food enzyme triacylglycerol lipase from *Trichoderma reesei* (strain RF10625)

Regulatory Review is a regular column featuring updates on regulatory matters concerning oils- and fats-related industries.

EFSA Panel on Food Contact Materials, Triacylglycerol lipases and Processing Aids

The European Food Safety Authority (EFSA) Panel on Food Contact Materials, Enzymes and Processing Aids has issued a Scientific Opinion on the food enzyme triacylglycerol. The panel concluded that when used in baking and cereal-based processes as intended, the food enzyme "does not give rise to safety concerns" and that although "the risk of allergic sensitization and elicitation reactions by dietary exposure cannot be excluded, the likelihood this would occur is "considered to be low."

Triacylglycerol acylhydrolase (EC 3.1.1.3) is produced with a genetically modified *Trichoderma reesei* strain RF10625 by AB Enzymes. The genetic modifications made in this production organism do not give rise to safety concerns, and the food enzyme is free from viable cells of the production organism and its recombinant DNA.

The food enzyme is intended to be used in baking and cereal-based processes at a recommended use level of up to 10 mg TOS/kg flour.

In baking processes, the triacylglycerol lipase is added to the raw materials during the preparation of the dough. It is used to facilitate the handling of the dough, improve the dough structure and behavior, as well as to reduce batter viscosity, thus contributing to an improved and consistent baking process.

In cereal-based processes, the triacylglycerol lipase is added to the raw materials during preparation of the dough to improve the dough processability and to reduce oil uptake during frying. It is used to improve the strength and stability of the dough, thus facilitating its handling.

The food enzyme remains in the dough. However, based on the thermostability data provided, it is expected that the triacylglycerol lipase is inactivated during baking.

Food consumption data were available from 35 different dietary surveys (covering infants, toddlers, children, adolescents, adults, and the elderly conducted in 22 European countries. Table 1 (page 36) provides an overview of the derived exposure estimates across all surveys.

Based on maximum use levels, dietary exposure to the food enzyme–total organic solids (TOS) was estimated to be up to 0.119 mg TOS/kg body weight (bw) per day in European populations.

TABLE 1. Summary of estimated dietary exposure to food enzyme–TOS in six population groups

Population group	Estimated exposure (mg TOS/kg body weight per day)					
	Infants	Toddlers	Children	Adolescents	Adults	The elderly
Age range	3–11 Months	12–35 months	3–9 years	10–17 years	18–64 years	≥ 65 years
Min–max mean (number of surveys)	0.008–0.035 (10)	0.029–0.074 (14)	0.035–0.065 (19)	0.018–0.040 (18)	0.012–0.027 (19)	0.011–0.025 (18)
Min–max 95th percentile (number of surveys)	0.033–0.119 (8)	0.067–0.105 (12)	0.059–0.118 (19)	0.034–0.078 (17)	0.025–0.047 (19)	0.021–0.043 (18)

*TOS: Total Organic Solids.

Genotoxicity tests did not raise a safety concern. Systemic toxicity was assessed by means of a repeated dose 90-day oral toxicity study in rats. The Panel identified a no-observed-adverse-effect-level of 1,000 mg TOS/kg bw per day, the highest dose tested, which when compared with the estimated dietary exposure, results in a margin exposure of at least 8,400. The similarity of its amino acid sequence with those of known allergens was searched, and no matches were found.

Four applications for other food enzymes have been introduced by the following companies: Cargill R&D Centre Europe for the authorization of the food enzyme Alternansucrase from *Leuconostoc citreum* (NRRL B-30894), Intertek Scientific & Regulatory Consultancy for the authorization of the food enzymes beta-galactosidase from *Bacillus circulans* (M3-1) and D-Fructose 3-epimerase from a genetically modified strain of *Escherichia coli* (W3110-TKO), and AB Enzymes GmbH for the authorization of the food enzyme triacylglycerol lipase from a genetically modified strain of *Trichoderma reesei* (RF10625). The Commission has verified that all four applications fall within the scope of the food enzyme regulation and contain all the elements required under that Regulation, and The European Commission has requested that the European Food Safety Authority conduct safety assessments on these food enzymes.

This article was excerpted from the full EFSA report at https://doi.org/10.2903/j.efsa.2019.5837, which was first published on October 22, 2019. Correspondence should be addressed to fip@efsa.europa.eu.

Meet Philip Ye

Member Spotlight is a regular column that features members who play critical roles in AOCS.

Fast facts

Name	Xiaofei (Philip) Ye
Joined AOCS	2011
Education	Ph.D. in biosystems and agricultural engineering from the University of Minnesota (Minneapolis–St. Paul, USA)
Job title	Professor and graduate coordinator
Employer	University of Tennessee (Knoxville, USA)
Current AOCS involvement	Associate editor of the Journal of the American Oil Chemists' Society, member of the Industrial Oil Products Division, meeting session chair

PROFESSIONAL

What's a typical day like for you?
"I teach every spring and fall and focus on research during the summer," explains Philip Ye. Office hours are in the early afternoon, so he reads papers to stay current or reviews papers as a *JAOCS* associate editor in the late afternoon. On nonteaching days, he prepares for teaching, grades, and "closes the door in order to write or revise papers or I go to the lab to get my hands dirty."

My favorite part of my job is…
"Pursuing new ideas for research and interacting with students and researchers worldwide is definitely the favorite part of my job," he says. "There's always something new."

Flash back to when you were 10 years old. What did you want to be when you grew up?
"I had no idea at that time," he says with a laugh, although since both of his parents were engineers in southwestern China, his playground was the agricultural equipment plant where his mother worked as a mechanical engineer. He thought at one point of being a farmer, but science won out in the end.

Why did you decide to do the work you are doing now?
"I wanted to do something different from my parents," Ye notes. "Food science was actually my first choice in college but they mysteriously put me in agricultural processing engineering. After college, I worked in a chemical fertilizer plant in China for six years. There, I witnessed the heavy environmental cost to water and air quality, which led to my interest in renewables and sustainability."

What event, person, or life experience has had the most influence on the direction of your life?
Ye showed no hesitation in answering this question. "Hands down, it was coming to the United States in 1996 for my master's and Ph.D. degrees. A very long journey but life-changing."

PERSONAL

How do you relax after a hard day of work?
"Recently, I've started running with my wife and daughter, who is a cross country runner in high school," he says. "I also enjoy talking with my family about the day or playing a round of golf."

What is the most impressive thing you know how to do?
"I played championship badminton in college, although I can't play at that level now. But I always remember pi up to 27 decimal points."

What skill would you like to master?
Ye is a self-taught country and folk guitar player who doesn't read music. "I think learning music theory would help me get to the next level," he says.

New Phase for Mercosur-Europe agreement

Leslie Kleiner

Latin America Update is a regular Inform *column that features information about fats, oils, and related materials in that region.*

On June 28, 2019, Mercosur signing countries Argentina, Brazil, Paraguay, and Uruguay reached a historical negotiation in the signing of the "Acuerdo de Asociación Estratégica con la Unión Europea (EU-Mercosur trade agreement)." Below, in Q&A format, are highlights from the agreement.

Q: What does this agreement entail?

The agreement allows for the integration of 800 million people between both regions, leading to EU companies becoming more competitive in the Mercosur region, by saving them €4 billion worth of duties per year [1]. For Mercosur, this agreement also increases exports arising from regional economies, consolidates supply chains in global markets, promotes investment in the countries, and guarantees transparency, reliability, and clear rules for both parties [2]. Specifically, Mercosur will liberate 91% of its imports from the EU over a 10-year transition period, which may extend to 15 years for Mercosur's most sensitive products. In exchange, the EU will liberate 92% of its imports from Mercosur over a 10-year transition period. Regarding tariffs, Mercosur and the EU will fully liberate 91% and 95% of lines in their schedules, respectively [3].

Q: What does the agreement mean for agricultural finished goods, such as ethanol?

Duties will be gradually eliminated on 93% of tariff lines for EU agro-food exports. These lines correspond to 95% of the export value of EU agricultural products. EU will liberate 82% of agricultural imports, with the remainder being subject to partial liberalization. Meats such as beef, poultry, and pork are addressed in the agreement, as well as other specific products like rice, honey, sweet corn, cheese, milk powders, and infant formula. For ethanol, 450 000 metric tons of ethanol for chemical uses, to be duty-free. 200,000 metric tons of ethanol for all uses (including fuel), to be with an in-quota rate 1/3 of Most Favored Nation (MFN) duty. The volume will be phased in six equal annual stages [3].

Q: What does the agreement mean in terms of raw materials, such as soybean?

The agreement will offer EU industries low-cost, high-quality raw materials by reducing or eliminating duties that Mercosur currently imposes on exports to the EU. This includes soybean products, such as feed for EU livestock. However, import and export price requirements, and import and export monopolies are prohibited [3].

Q: Are there specifications on rules of origin?

Rules of origin will allow exporters and importers from both parties to benefit from the tariff reductions under the agreement. Rules of origin are specified under section A of the agreement as well as in the Annexes. Section A defines wholly obtained products, the absorption rule, and the principle of territoriality. Section B on Origin Procedures specifies that claims for preferential tariff treatment must be based on a statement of origin by the exporter (with maximum transitional period of 5 years for Mercosur). Section C contains miscellaneous issues and transitory provisions. Product Specific Rules of Origin (PSR), reflect the rules of origin applicable in recent EU Free Trade Agreements, particularly for key EU export sectors. There are only limited exceptions or deviations to the normal rules, which take into account the nature of Mercosur's agricultural exports to the EU (e.g., coffee, soybean) and other specific requests [3].

Q: What are the general topics addressed in the agreement?

The agreement has 17 main topics: 1. Trade in Goods, 2. Rules of Origin, 3. Customs and Trade Facilitation, 4. Trade Remedies, 5. Sanitary and Phytosanitary Measures (SPS), 6. Dialogues, 7. Technical Barriers to Trade (TBT), 8. Services and Establishment, 9. Public Procurement 10. Competition, 11. Subsidies, 12. State-owned Enterprises, 13. Intellectual Property Rights, including Geographical Indications, 14. Trade and Sustainable Development, 15. Transparency, 16. Small and Medium-sized Enterprises, 17. Dispute Settlement [3].

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[1] https://trade.ec.europa.eu/doclib/press/

[2] https://www.mercosur.int/documento/mercosur-ue/

[3] https://trade.ec.europa.eu/doclib/docs/2019/june/tradoc_157964.pdf

Latin America Update is produced by Leslie Kleiner, a senior research scientist and contributing editor of *Inform*.

PATENTS

Bio-based acrylic monomers

Voronov, A., *et al.*, NDSU Research Foundation, US10315985, June 11, 2019

The invention provides a bio-based acrylic monomer, particularly a plant oil-based acrylic monomer, which is well-suited for emulsion polymerization and latex formation in aqueous medium. Polymers and copolymers formed from the bio-based acrylic monomer are also provided. The invention further provided methods for making the monomer from bio-based triglycerides or fatty esters.

Emulsions with polymerized oils and methods of manufacturing the same

Kurth, T., *et al.*, Cargill, Inc., US10316192, June 11, 2019

Described herein is an emulsion for use in asphalt rejuvenation applications, comprising an oil phase comprising (1) a polymerized oil comprising a polymeric distribution having about 2 to about 80 wt % oligomer content, a polydispersity index ranging from about 1.0 to about 5.0, and sulfur content less than about 8 wt %; and (2) an aqueous phase, comprising a surfactant. The emulsion may be incorporated into asphalt paving, roofing, and coating applications and especially aged or recycled asphalt thereby obtaining rejuvenated asphalt.

Conversion of lipids into olefins

Ullah, A., *et al.*, University of Alberta, US10316255, June 11, 2019

A method of conversion of a lipid to an olefin product includes heating a mixture of unsaturated triacylglycerols or alkyl esters of unsaturated fatty acids and a reactant olefin with microwave irradiation, in the presence of a ruthenium complex catalyst.

Process for removing chloropropanols and/or glycidol, or their fatty acid esters, from glyceride oil, and an improved glyceride oil refining process comprising the same

Goodrich, P., *et al.*, The Queen's University of Belfast and Evonik Degussa GMBH, June 11, 2019

The present invention is directed to a basic ionic liquid treatment for removing chloropropanol and/or glycidol, or their fatty acid esters, from glyceride oil, as well as a process for refining glyceride oil which includes the basic ionic liquid treatment. The present invention also relates to uses of the basic ionic liquid and glyceride oil compositions obtained from the ionic liquid treatment.

Compositions and methods for altering the rate of hydrolysis of cured oil-based materials

Faucher, K.M., *et al.*, Atrium Medical Corp., US10322213, June 18, 2019

Disclosed herein is the correlation of chemical properties of oils with the physical properties of a resulting cured oil composition. Also disclosed are biocompatible materials and coatings for medical devices prepared using enriched oils and methods for enhancing or modifying the physical and chemical characteristics of cured oils by enriching such oils with fatty acid alkyl esters. Methods of tailoring the properties of biocompatible materials and coatings to deliver one or more therapeutic agents are also provided.

BPA-free coatings

Lalgudi, R.S., *et al.*, Ohio Soybean Council, US10323160, June 18, 2019

Provided are polytriglyceride-AAG compositions, and corresponding coatings and coated articles. Also provided are methods for preparing the polytriglyceride-AAG compositions, and corresponding reagents including beta-ketoimide compositions and triglyceride-AAG (acetoacetyl group) compositions. Coatings using the polytriglyceride-AAG compositions may be useful for, e.g., replacing bisphenol-A cross-linked coatings used in food and beverage containers, coating metal articles, and the like.

Polyols suitable for hot-molded foam production with high renewable resource content

Hager, S.L., *et al.*, Covestro LLC, US10323212, June 18, 2019

Polyols are produced by an alkoxylation process in which a vegetable oil containing hydroxyl functional groups is combined with a DMC catalyst to form a mixture, the DMC catalyst is then activated by adding ethylene oxide and/or propylene oxide to the vegetable oil/catalyst mixture, and ethylene oxide and propylene oxide are added to the mixture containing activated DMC catalyst in amounts such that the total of percentage of ethylene oxide in the polyol plus percentage of primary hydroxyl groups in the polyol produced is from 50 to 77% and the percentage of primary hydroxyl groups is at least 30% but less than 50%. These polyols are useful for the production of molded polyurethane foams, particularly, hot-cure molded polyurethane foams.

Patent information was compiled by Scott Bloomer, a registered US patent agent and Director, Technical Services at AOCS. Contact him at scott.bloomer@aocs.org.

Introducing *JSD*'s new Editor-in-Chief

The *Journal of Surfactants and Detergents* (*JSD*) has a new Editor-in-Chief (EIC): Doug Hayes. As *JSD*'s 5th EIC, the professor of biosystems engineering at the University of Tennessee (UT) in Knoxville, will shape the future of an AOCS journal that has been the leading source of peer-reviewed original research related to the fats and oils industries since 1998.

Hayes brings an incredible depth of experience to the role. In addition to his already busy job as professor of biosystems engineering at UT, he is also an adjunct professor of chemical and biomolecular engineering at UT, a guest professor at Wuhan Polytechnic University and Jinan University (Guangzhou, China), and a UT-Oak Ridge National Laboratory joint faculty member. Hayes received the UT Institute of Agriculture's Impact Award in 2017, and its and John J. and Dorothy G. McDow Faculty Excellence Award in 2019. He has more than 80 publications in peer-reviewed journals, has written more than 20 book chapters, and has co-edited three books in interest areas that include surfactant self-assembly systems, biobased products, bioplastics, and applied enzymology.

A longstanding member of AOCS, Hayes became a reviewer for the *Journal of the American Oil Chemists' Society* (*JAOCS*) when he was a postdoc at the US Department of Agriculture. He became an Associate Editor (AE) for *JAOCS* in 1999, an AE for *JSD* in 2010, and a Senior Associate Editor for *JAOCS* in 2013.

Haye's passion for and dedication to serve as Editor-in-Chief (EIC) of *JSD* began when he served as an Associate Technical Editor (ATE) under the journal's 3rd EIC, Jean Louis-Salager. "Jean-Louis exemplified passion as an editor and advocate of the journal. He reviewed each and every manuscript prior to assigning to the ATEs, and he provided useful comments on his assessment of the manuscripts," says Hayes, who adds that Salager worked hard during the Annual Meetings to procure new manuscripts from prospective authors through engagement.

In 2014, Hayes served as Chair of the search committee that ultimately chose George Smith to succeed Salager and become the 4th EIC of *JSD* from 2015–2019. Serving on the journal search committee taught Hayes that *JSD* has a unique mission in the colloids/interfaces publishing space due to its emphasis on the surfactants themselves (their synthesis, characterization, and application), the heavy involvement of the industrial sector in authorship, and a deep affiliation with a passionate professional society and dedicated professional staff.

Hayes' first goal as *JSD*'s new EIC is to increase the journal's Impact Factor to 2.0 or above, so it is competitive with other journals in the colloids/surfactants space. "A secondary goal would be to increase recognition of the Technical Editors, Associate Technical Editors, and reviewers who play such a key role in the success of the journal," he says.

His third goal is to enhance, broaden, and integrate the *JSD* editor and reviewer communities—something that should come naturally to him since he has actively championed technical writing and peer review since graduate school, when he helped the younger students in his department with writing and presentations and later provided similar help to people in his research group, especially by providing them with opportunities to serve as peer reviewers.

In an article Hayes wrote for the April 2019 issue of *Inform*, "How peer reviewing has helped my career," he explained why peer reviews are the key step in insuring quality journal publications, and how reviewing helps young scientists improve their technical writing skills, sharpen critical their thinking, deepen knowledge of their subject area, and communicate and assess other scientists' work in a manner that is fair, diplomatic, beneficial, and not condescending.

"Perhaps the most important benefit of peer reviewing has been the privilege of helping colleagues and students improve their papers," he wrote. "Others have poured time and effort into helping me, and it is an honor to be able to return the favor." As EIC of *JSD*, Hayes will have plenty of opportunities to do just that.

EXTRACTS & DISTILLATES

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ANA Analytical
EAT Edible Applications
H&N Health and Nutrition
PRO Processing
S&D Surfactants and Detergents
BIO Biotechnology
LOQ Lipid Oxidation and Quality
IOP Industrial Oil Products
PCP Protein and Co-Products

REVIEW ARTICLES

ANA Low-field NMR for quality control on oils

Rudszuck, T, *et. al., Magn. Reson. Chem. 57*: 777–793, 2019, https://doi.org/10.1002/mrc.4856.

Oil is a prominent, but multifaceted material class with a wide variety of applications. Technical oils, crude oils, as well as edibles are main subclasses. In this review, the question is addressed how low-field NMR can contribute in oil characterization as an analytical tool, mainly with respect to quality control. Prerequisite in the development of a quality control application, however, is a detailed understanding of the oils and of the measurement. Low-field NMR is known as a rich methodical toolbox that was and is explored and further developed to address questions about oils, their quality, and usability as raw materials, during production and formulation as well as in use.

EAT S&D Colloidal aspects of digestion of Pickering emulsions: experiments and theoretical models of lipid digestion kinetics

Sarkar, A., *et. al., Adv. Colloid Interfac. Sci. 263*: 195–211, 2019, https://doi.org/10.1016/j.cis.2018.10.002.

Lipid digestion is process that is largely governed by the binding of the lipase-colipase-biosurfactant (bile salts) complex onto the surface of emulsified lipid droplets. Pickering emulsions, i.e., emulsions stabilized by micron- to nano-sized particles, have the potential to modulate lipid digestion. The particles can be resilient to desorption by these intestinal biosurfactants and provide stability against coalescence of the emulsion droplets. This review summarizes the current state of understanding of these processes and proposes models and future experiments that could enable the design of emulsion systems that delay lipid digestion or control the release of lipidic active molecules in soft matter systems, such as food, personal care, pharmaceutical, healthcare and biotechnological applications.

EAT PCP Plant-based milks: a review of the science underpinning their design, fabrication, and performance

McClements, D.J., *et. al., Compr. Rev. Food Sci. F. 18*: 2047–2067, 2019, https://doi.org/10.1111/1541-4337.12505.

Many consumers are interested in decreasing their consumption of animal products, such as bovine milk, because of health, environmental, and ethical reasons. The food industry is therefore developing a range of plant-based milk alternatives. This excellent article reviews current understanding of the development of these materials.

EAT Palm oil on the edge

Gesteiro, E., *et. al., Nutrients 11*: 2008, 2019, https://doi.org/10.3390/nu11092008.

Internationally recognized Spanish experts in the food industry, nutrition, toxicology, sustainability, and veterinary science met in Madrid on July 2018 to develop a consensus about palm oil (PO) as a food ingredient. Their aim was to provide a useful, evidence-based point of reference about PO. This report provides an interesting summary of their findings.

PRO Algae as green energy reserve: technological outlook on biofuel production

Anto, S., *et al., Chemosphere 242*: 25079, March 2020, https://doi.org/10.1016/j.chemosphere.2019.125079.

Depletion of fossil fuel sources and their emissions have triggered vigorous research in finding alternative and renewable energy sources. In this regard, algae are being exploited as a third-generation feedstock for the production of biofuels such as bioethanol, biodiesel, biogas, and biohydrogen. However, algal based biofuel does not reach successful peak due to the higher cost issues in cultivation, harvesting, and extraction steps. Therefore, this review presents an extensive detail of deriving biofuels from algal biomass starting from various algae cultivation systems like raceway pond and photobioreactors and its bottlenecks. Evolution of biofuel feedstocks from edible oils to algae have been addressed in the initial section of the manuscript to provide insights on the different generation of biofuel. Different configurations of photobioreactor systems used to reduce contamination risk and improve biomass productivity were extensively discussed. Photobioreactor performance greatly relies on the conditions under which it is operated. Hence, the importance of such conditions like temperature, light intensity, inoculum size, CO_2, nutrient concentration, and mixing in bioreactor performance have been described. As the lipid is the main component in biodiesel production, several pretreatment methods such as physical, chemical, and biological for disrupting cell membrane to extract lipid were comprehensively reviewed and presented. This review article had put forth the recent advancement in the pretreatment methods like hydrothermal processing of algal biomasses using acid or alkali. Eventually, challenges and future dimensions in algal cultivation and pretreatment process were discussed in detail for making an economically viable algal biofuel.

ORIGINAL ARTICLES

ANA H&N Physicochemical and functional properties of gamma-aminobutyric acid-treated soy proteins

Wang, Y., *et al.*, *Food Chem. 295*: 267–273, 2019, https://doi.org/10.1016/j.foodchem.2019.05.128.

Gamma-aminobutyric acid (GABA) is a non-protein amino acid with various health benefits. GABA enrichment in soy products such as tempeh, doenjang, and soymilk have been reported. However, no study has explored how GABA interacts with soy proteins and affects their properties. The current study investigated the physicochemical and functional properties of soy proteins in a 4% (w/v) slurry treated with 0.2–1.0% of GABA at 80, 90, and 100°C. The addition of GABA significantly ($P < 0.05$) reduced the average particle size and increased the zeta-potential and intrinsic fluorescence intensity of the soy protein slurries. GABA treatment resulted in concentration-dependent increases ($P < 0.05$) in soy protein solubility, viscosity, rheology, emulsifying and foaming properties. This study, for the first time, investigated the effects of GABA on the properties of soy proteins. The findings would be useful in soy product formulation when GABA is added as a functional ingredient.

When you also consider "Brassica-enriched wheat bread: unraveling the impact of ontogeny and breadmaking on bioactive secondary plant metabolites of pak choi and kale," *Food Chem. 29*: 5412–22, 2019, combining ingredients from these two abstracts is an interesting idea. Conceptually, such a combination could also be used as a delivery agent for micro ingredients that sooth intestinal microbiota and provide support to the gut-brain axis.

EAT H&N Adding apple pomace as a functional ingredient in stirred-type yogurt and yogurt drinks

Wang, X., *et al.*, *Food Hydrocoll. 100*: 105453, 2020, https://doi.org/10.1016/j.foodhyd.2019.105453.

Apple pomace (AP) was processed into a freeze-dried powder to add into stirred-type yogurt to create 1, 2, and 3% (w/w) AP-fortified yogurt. Both texture analysis and rheological testing were used to evaluate the effect of AP on the structure and texture of yogurt during cold storage. The results indicated that apple pomace altered the structure of stirred yogurt, making it firmer and more cohesive, increased its viscosity, and significantly reduced whey release during cold storage. Stronger influence on the parameters was observed at higher AP concentrations. Apple pomace added to a diluted yogurt system has the potential to stabilize the acid drink and reduce the sedimentation of protein aggregates. Addition of AP to already fermented milk gel allowed a higher concentration of AP (up to 6% w/w) to be incorporated, which made the stirred yogurt and yogurt drinks a vehicle for delivering a higher level of dietary fiber and phytochemicals (as compared to AP added to milk prior to fermentation). This study demonstrated that apple pomace has a potential as a natural stabilizer as well as a dietary fiber source in stirred type yogurts and yogurt drinks.

EAT H&N Cistus extract as a valuable component for enriching wheat bread

Mikulec, A., *et al.*, *LWT–Food Sci. Technol. 118*: 108713, 2020, https://doi.org/10.1016/j.lwt.2019.108713.

The aim of the study was to use cistus extract for the production of wheat bread and determine its impact on selected physicochemical, microbiological, and organoleptic characteristics, the color of the crumb, changes in the crumb texture, polyphenol profile, and the total polyphenol content. Breads with 5 and 7.5% cistus extract were characterized by lower average scores for taste and smell, compared to wheat bread. During storage (up to 5 days) the largest increase of crumb hardness was observed for wheat bread, as much as 72.89%, compared to the first day of storage, in contrast to bread with 5% cistus extract (29.03%). The replacement of water by cistus extract influenced the color of the crumb by increasing its browning index from 30.92 (standard bread) to 66.47 (7.5% cistus extract). The cistus extract contributed to an improvement of the microbiological quality of the bread. The addition of the cistus extract influenced the polyphenol content by increasing it from 8.88 (wheat bread) to 78.71 mg/100 g (breads with 7.5% cistus extract) and the total polyphenol content from 62.81 to 105.81 mg GAE per 100 g of product, compared to the wheat bread.

H&N Hydroxyl groups in synthetic and natural-product-derived therapeutics: a perspective on a common functional group

Cramer, J., *et al.*, *J. Med. Chem. 62*: 8915–8930, 2019, https://doi.org/10.1021/acs.jmedchem.9b00179.

Any chemist on a cursory review of the structures of prescription drugs and natural products will notice a basic difference in the two classes of compounds. Natural products are primarily comprised of C, H, and O molecules followed by nitrogen and phosphorus. When nitrogen and phosphorous are used in prescription drugs, they are usually incorporated in a different way. This is an important difference to note if one wants to understand the impact evolution has had on natural products and why they function the way they do.

By forming extended hydrogen-bond networks, the contribution of hydroxyl groups to affinity can reach several orders of magnitude. However, because of the high directionality of their interactions, a maximal affinity gain can only be achieved when the ligand scaffold allows a perfect spatial fit with the binding site. In contrast to the broad potential of hydroxyl groups for molecular recognition is their exceptionally high desolvation penalty, which can equally reduce binding affinity. As a consequence, alcohols are rarely present in synthetic drugs but predominantly found in therapeutics derived directly or inspired from natural products, which were shaped under evolutionary pressure. In this perspective, advantages as well as drawbacks influencing the use of OH groups in medicinal chemistry are discussed and illustrated with four exemplary case studies. Additionally, guidelines for drug design are derived from common features found in existing therapeutics.

LOQ EAT H&N Converting industrial organic waste from the cold-pressed avocado oil production line into a potential food preservative

Permal, R., *et al.*, *Food Chem. 30*: 125635, 2020, https://doi.org/10.1016/j.foodchem.2019.125635

The production of commercial cold-pressed avocado oil (CPAO) generates large quantities of organic wastes, such as pomace, seeds, peels, and wastewater. During the early harvest season, for every 1,000 kg of avocado fruits processed, roughly 80 kg of oil is produced, and wastewater accounted for the highest proportion (500 kg). Therefore, it is important to find an alternative application for this wastewater rather than its direct disposal into landfills. Proximate analysis, total phenolic content (TPC), and antioxidant assays were conducted on the avocado wastes. Avocado wastewater (AWW) was spray-dried into powder at different temperatures from 110°C–160°C, which concomitantly increased the TPC and antioxidant capacities of the AWW powder. The powder was further applied as a preservative in pork sausages and was found to be effective in preventing lipid oxidation.

LOQ ANA Effects of natural ingredients on the shelf life of chicken seasoning

Tian, H.-X., *et al.*, *Food Chem. 293*: 120–126, 2019, https://doi.org/10.1016/j.foodchem.2019.03.084.

The kinetic model used in this study could facilitate the discovery of more effective natural preservatives.

The effects of the natural ingredients *Angelica sinensis* (AS) and *Codonopsis pilosula* (CP) on the shelf life of chicken seasoning were investigated. Color differences and sensory evaluation were used to indicate sensory differences. Changes in volatiles were monitored. The rate of increase in the color value a* of the AS and CP samples was lower than that in the control. Rancid flavor appeared later in the AS and CP samples than in the control. The levels of aldehydes, ketones, and alkenes increased during storage. A kinetic model was built based on the proportion of aldehydes (main marker), to predict shelf life. The predicted shelf life at room temperature was 60 days for the control, 114 days for AS, and 89 days for CP. The shelf life of chicken seasoning could be prolonged with AS and CP. This kinetic model can be used to predict the shelf life of chicken seasoning.

LOQ EAT Effect of different types of active biodegradable films containing lactoperoxidase system or sage essential oil on the shelf life of fish burger during refrigerated storage

Ehsani, A., *LWT–Food Sci. Technol. 117*: 108633, 2020, https://doi.org/10.1016/j.lwt.2019.108633.

The present study aimed to control the spoilage of fish burger of common carp meat kept at refrigerated temperature (4 ± 2°C) during 20 days storage using active biodegradable films containing lactoperoxidase system (LPS) or sage essential oil (SEO). Fish burgers were prepared from minced common carp meat and were wrapped in chitosan (CH), alginate (AL,) and gelatin (ZH) films containing SEO or LPS. Different groups were kept in the refrigerated temperature and samples taken at day 0, 5, 10, 15, and 20 of storage time for determination of Total Viable Count (TVC), psychrotrophic bacterial count (PTC), *Pseudomonas* spp. (PSC) and *Shewanella* spp (ShC). Also, TBARS, pH and sensory properties of the groups were checked during refrigeration. Chitosan films containing LPS were the most effective package to significantly suppress the increase of TVC, PTC, *Pseudomonas* spp. and *Shewanella* spp, and TBARS during 20-day storage at refrigerated condition compared with other treatments ($P<0.05$). Moreover, the alginate

and chitosan films containing LPS and SEO had the higher ultimate pH ($P<0.05$). The results of this study indicated that the chitosan film containing LPS extend the shelf life of fish burgers in comparison by other treatments and control for 5 days.

PCP H&N Bioactive compounds obtained from oilseed by-products with subcritical fluids: effects on *Fusarium verticillioides* growth

Bodoira, R., *et al.*, *Waste Biomass Valor,* online October 2019, https://doi.org/10.1007/s12649-019-00839-y.

Recovery of bioactive compounds from wastes is gaining interest because they could add value to by-products arising from, for example, the oil extraction processes. In this work, green solvent extraction (water/ethanol under sub-critical conditions) was used to obtain bioactive compounds from peanut, sesame, and pistachio agro-industrial by-products. Extracts were analyzed in their overall chemical composition and tested on growth, ergosterol and fumonisin FB_1 production by *Fusarium verticillioides*. The effects of the extracts on fungal growth rate and biochemical markers were not univocal and could be associated to differences in their chemical profiles. Extracts obtained from peanut skin—composed mainly by monomeric and dimeric flavonoids—caused significant reductions in fungal growth rate but increased FB_1 production. Extracts from sesame seeds—dominated by furofuran-type lignans—did not have a clear inhibitory effect on growth rate but strongly reduced both FB_1 and ergosterol production. Extracts from pistachio nuts—characterized by monomeric flavonoids and gallic acid derivatives—showed minor effects on both fungal growth rate and biochemical markers. Sub-critical fluid extraction of peanut skin and defatted sesame seeds may provide an efficient method to obtain extracts rich in phenolic and lignan compounds with potential use as antifungal agents.

PRO Extraction of oil from wet Antarctic krill *(Euphausia superba)* using a subcritical dimethyl ether method

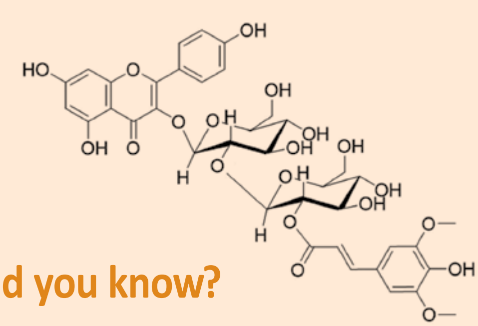
Liu, S., *et al.*, *RSC Adv. 59*: 34274–34282, 2019, https://doi.org/10.1039/C9RA06238F.

In this study, a novel method for obtaining high-quality krill oil from wet Antarctic krill by using subcritical dimethyl ether (SDE) was proposed. A response surface design was used to obtain the best SDE extraction parameters. The optimum extraction efficiency of 93.77 ± 0.92% was obtained at a stirring speed of 1030 rpm, temperature of 47°C, and dynamic extraction time of 90 min. Compared with n-hexane, ethanol, supercritical CO_2, and subcritical n-butane extraction, the krill oil extracted by SDE exhibited low peroxide values (1.46 ± 0.26 mmol kg^{-1}), high astaxanthin (218.06 ± 4.74 mg kg^{-1}), phosphatidylcholine (PC) (33.95 ± 0.65%), and phosphatidylethanolamine (PE) (11.67 ± 0.23%) content. Moreover, krill oil extracted by SDE has high levels of EPA (16.38 ± 0.05%) and DHA (7.91 ± 0.07%). SDE extraction proved to be an efficient and safe method for extraction of quality krill oil from wet Antarctic krill, and it could be a promising method for oil extraction in wet food in future.

PRO Development of a tomato pomace biorefinery based on a CO_2-supercritical extraction process for the production of a high-value lycopene product, bioenergy, and digestate

Scaglia, B., *et al.*, *J. Cleaner Prod. 243*: 118650, 2020, https://doi.org/10.1016/j.jclepro.2019.118650.

Tomato peels and seeds (TP) are the most abundant canning industry waste used to produce biogas. TP is rich in lycopene (lyc) and represents a more sustainable feedstock than tomato fruits. It was therefore chosen as feedstock, together with supercritical CO_2 extraction (SFE-CO_2) technology, to develop a TP-SFE-CO_2 biorefinery. Two TP were tested, and although TP-SFE-CO_2 parameters were the same, lyc recoveries depended on peel structure changes that occurred during the pre-SFE-CO_2 drying step. Higher moisture (102.7 g kg–1 wet weight) permitted 97% lyc recovery and gave a water-in-oil emulsion as extract. Mass balance confirmed that lyc isomerization did not cause lyc losses. After significant oil extraction, exhausted TP showed a biodegradability 64% higher than the raw one, attributable to fiber structure disruption. The proposed biorefinery (SFE-CO_2+anaerobic digestion) was estimated to have a positive economic revenue (+787.9 € t–1 TP) in contrast with conventional TP management.



Did you know?

Worldwide, about 1.12 million tons of crude protein are produced annually from rapeseed oil, but because protein isolates obtained from rapeseed have an intense, bitter off-taste, rapeseed protein is only used for animal feed and not as a protein source for humans. Mass-spectrometric analysis and taste tests conducted by researchers at the Technical University of Munich, Germany, revealed that a compound called kaempferol 3-O-(2‴-O-sinapoyl-beta-sophoroside) is the key substance that makes protein extracts from rapeseed inedible (Hald, *et al.*, 2019, https://pubs.acs.org/doi/10.1021/acs.jafc.8b06260). Its structure is pictured here.