The commercialization of Ahiflower™ oil, a new and sustainable source of omega-3 fatty acids

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This article is not a technical or scientific paper. It is, rather, a distillation of the processes and activities our company has adopted to introduce an entirely new oilseed crop and take it to commercial reality. With the correct management, this new crop could be a game changer in plant-derived essential fatty acids (FA) and serve as a model for other new or specialty crops.

The search for sustainable, cost-competitive, and biologically effective sources of omega-3 (ω-3) FA that can provide meaningful consumer value has attracted a great deal of commercial interest and is largely a market driven-phenomenon, implying an imbalance between emerging demand and existing supply. Broadly speaking, there are three major commercial feedstock origins: algae, marine plants, and terrestrial plants. Each source has unique advantages and disadvantages, and increasing biological efficacy often comes at an elevated cost accompanied by increased concerns over sustainability and provenance. Additionally, the FA eicosapentaenoic acid (EPA; C20:5ω-3) and docosahexaenoic acid (DHA; C22:6ω-3) are generally believed to deliver greater health benefit than the shorter, less unsaturated precursor molecule α-linolenic acid (ALA; C18:3ω-3). EPA and DHA are traditionally derived from algal and marine sources whereas ALA is typically found in oils from various plants, notably flax, chia, and canola, which contain between 15% and 65% ALA in their oil fractions.

Scientific studies generally agree that the major rate-limiting step for converting ALA to EPA in humans is that of initially introducing a fourth double bond, effectively converting ALA (C18:3ω-3) into stearidonic acid (SDA; C18:4ω-3). This reaction is mediated by the Δ6-desaturase enzyme. The conversion of ALA to EPA in humans is reportedly about 5%, whereas SDA is converted to EPA with an efficiency of up to 30%. There is, therefore, a significant advantage for having higher levels of SDA in ingested triglycerides to increase the EPA content in tissue at much lower intake levels as compared to ALA.

Although some microorganisms can synthesize FA with more than four double bonds, rarely is this seen at meaningful levels in terrestrial plant oils. Even where some plants synthesize very long chain FA such as erucic acid (C22:1ω-9) and nervonic acid (C24:1ω-9), those having more than two double bonds are unusual, those having more than three double bonds are extremely rare, and those having more than four double bonds are virtually unheard of.

This was the background against which our company, Technology Crops International LLC, sought to find a plant species that could produce high levels ω-3 polyunsaturated FA (C18:3 or C18:4) in an oil-rich seed suitable for commercial-scale oil recovery. We also needed a seed that would let us use traditional oilseed processing and oil refining techniques and equipment. Additionally, it had to meet all of our supply chain criteria for scalable and sustainable production. For ease of operational management, we broke the supply chain down into three pieces: *Grow, Make,* and *Sell*.

This case study in commercializing a new oilseed crop is a how-to guide to managing three critical pieces of the supply chain:

- **Growing a new oilseed crop**
- **Making the finished oil**
- **Selling a new product**

FIG. 1. A crop of *Bugglosoidies arvensis* in full flower in New Zealand.

GROW

In modeling a specialty crop supply chain from soil to oil, every step needs detailed consideration. For the *Grow* piece of the chain, getting grower buy-in is critical. Before considering cultivating a specialty crop, farmers demand good genetics; good agronomic support; a robust toolkit of herbicides, fertilizers, and pesticides; a risk management plan (unlike most commodity crops, specialty crops do not benefit from federally supported insurance programs); and the knowledge that they are investing in growing a crop that has a strong and profitable market to move into (Fig. 1).

Beyond the growers' control there are environmental matters; for example, is the species noninvasive? How does it fit into a crop rotation program? How does its quality change with climate (weather patterns greatly impact FA synthesis), and how does it integrate with other flora and fauna on the farm (e.g., insect pollination)? Neither scalability—going from small field trial plots to thousands of acres—or sustainability (let's define this as ensuring that the value delivered is greater than the value that's depleted) can be accomplished if the *Grow* model is wrong.

Many literature sources identify the FA composition of oil-containing plant seeds, which helped us to narrow down the search to a handful of plant families that (i) can be grown

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Cultivation challenges

Echium plantagineum has inherently low oil productivity (approximately 20 pounds per acre, or 22 kilograms per hectare), making it an expensive oil to produce, thereby limiting its application and inclusion. It has invasiveness issues and livestock toxicity associations that have resulted in its cultivation being prohibited in certain parts of the world, including several regions in North America. Despite significant investment in developing adaptation strategies to row crop agriculture, *Echium* still proves a challenging species to integrate into modern agricultural practices; however, a small yet robust market has developed for the oil in nutritional and skin care applications.

under temperate conditions, (ii) appear to be malleable in terms of possible domestication, thus removing reliance on wild crafting (the gathering or collecting of uncultivated material from the wild), and (iii) meet the commercial proposition intended. In the beginning, we screened hundreds of candidate species, mostly belonging to the Boraginaceae family, ranging from *Myositis* (the common forget-me-not) through to the many different members of the *Echium* species (such as *Echium plantagineum* also known unaffectionately in Australia as Paterson's curse or salvation Jane). We also considered other currently commercially available oils that have ALA and SDA content, most notably hemp and blackcurrant seed; however, neither met the criterion of scalability or having sufficiently elevated levels of these FA. In the late 1990s, we embarked upon commercializing *E. plantagineum* as the preferred candidate crop to deliver ALA and SDA, containing approximately 32% and 13%, respectively. This species had another benefit, namely, modest levels of γ-linolenic acid (GLA; C18:3 ω-6), present at approximately 5% of total FA. From the outset, Echium production presented major challenges in each of the *Grow, Make,* and *Sell* categories.

Therefore, our search continued and focused on the species *Bugglossoidies arvensis* (also a member of the borage family), a somewhat unp rolific wild species found growing in many regions of the world. While its *Grow* characteristics did not initially meet our criteria, intuitively we felt they might, if a concerted investment were made to understand its physiology and how to encourage it to adapt to modern row crop cultivation. After a global germplasm search, selection, and evaluation program that is in its sixth year, we have now registered the first varieties under Plant Variety Protection (PVP) protocols and have trademarked this new crop, which we call Ahiflower™. These varieties represent the most prolific or physiologically suited wild types that were found and we have now assembled and evaluated the world's largest repository of genetics of the species.

Understanding a plant's evolutionary mechanisms and then working with them to produce stable, reliable yields when cultivated is both a humbling and rewarding process. The very traits that enable its survival and competition as part of a biodiversity-rich wild environment are often the same ones that make it wholly unsuitable for cropping. Dormancy, low vigor, and poor uniformity as well as tolerance to climatic and environmental stimuli all need researching and understanding. These hurdles are inherent to the strategy of choosing biodiversity over biotechnology to deliver your target output. We chose biodiversity, largely driven by strong customer preference for a natural product, and our core competence within the life sciences is in bringing specialty crops to market, rather than being a genetics and plant breeding business.

Yield is king

In row crop agriculture, yield is invariably king. Increasing productivity drives price down and reduces risk. Lowering costs and managing risk enable scalability, which in turn provides significant market growth potential. Understanding demand elasticity with price is crucial to success.

After various setbacks that were more than offset by advancements, the crop is now being commercially cultivated under strict grower licensing agreements in both the Northern and Southern Hemispheres, to deliver two annual crop cycles. Field performance is highly respectable, with seed yields of 900 pounds per acre (1,000 kilograms per hectare) being achieved (approximately 250 pounds of oil per acre, or 280 kilograms per hectare). Our strategy is to work with best-in-class growers, those that want to become part of a fully integrated supply chain and to be innovative with their agronomic and business practices, and those that have a real passion for producing value-enhancing specialty crops. Interestingly, many of these same growers produce meadowfoam, echium, borage, and crambe oils under contract also and are willing to try other new species as the opportunity arises.

Crop Assured 365™

This is Technology Crops International's proprietary traceability and quality assurance program enabling the contents of every soft gel cap containing Ahiflower™ seed oil to be traced back to the field in which it originated. Growers, truckers, processors, and handlers are all required to keep records and follow documented procedures to ensure that the chain of custody is rigorously protected. Increasingly, the market for dietary supplements and skin care ingredients is demanding assurances about the authenticity and provenance of raw materials, which greatly benefits using a fully integrated supply chain, 365 days a year. Crop Assured 365™ operates as both a containment and exclusion tool by ensuring no leakage of the target product, so that intellectual property control is possible, while prohibiting the introduction of foreign material such as genetically modified organisms or maintaining quality criteria such as organic certification.

MAKE

Assuming the *Grow* piece can deliver a stable and reliable raw material, we move to *Make*. This captures everything from when the crop is harvested through to the manufacturing of the finished oil. Similar to other oilseeds, the process of oil recovery and refining must be modified to the characteristics of the seed and oil itself. Protocols for seed cleaning and drying, mechanical pressing (expelling), solvent extraction and oil refining—including neutralization, bleaching and deodorizing—have to be developed. Once manufactured, the development of analytical testing methodologies, oil stabilization strategies (to prevent deterioration through oxidation) and product formulation or oil delivery systems (such as soft gel capsules and functional food ingredients) are necessary so that a high-quality, safe, efficacious, and consumer-acceptable product can be delivered. Under correct storage conditions, Ahiflower™ seed can be held for 12 months

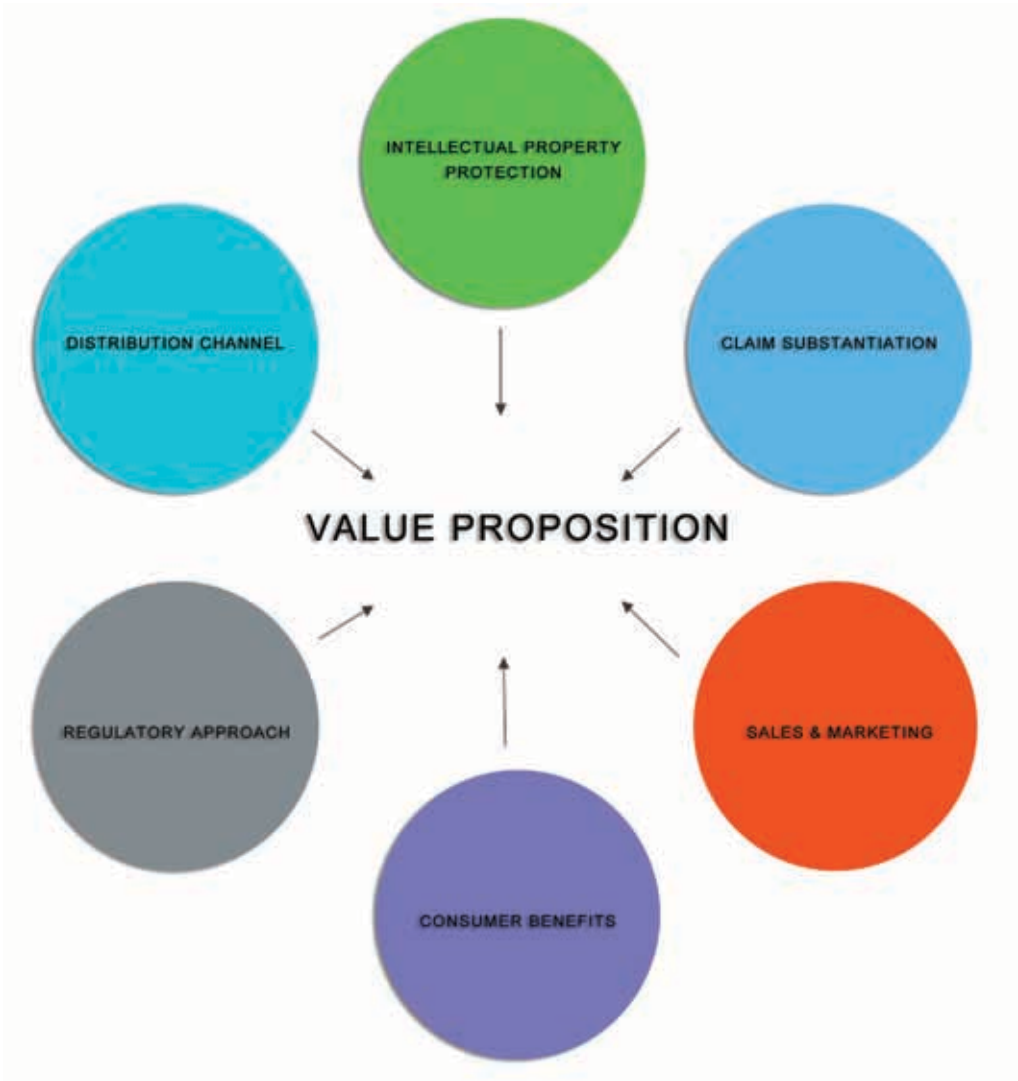

FIG. 2. In developing a value proposition, the major contributing factors need to be identified and understood. They change, subject to the end use application. For example, Ahiflower™ will feature in dietary supplements, skin care products, animal feed ingredients and as a functional ingredient in human food products. Each market has its own unique language and communication channels.

before crushing and oil stored for six months after refining by using suitable protective antioxidant measures.

Bearing in mind that the percentage of oil in most oil-containing seeds is between 20% and 50% (*B. arvensis* has 25%), a significant amount of biomass co-product remains to be managed once the oil is removed. Invariably this goes into animal feed, which in itself is an entirely different market development process, with different regulatory and performance criteria, yet one that greatly drives the overall commercial success of the oil.

SELL

This is where reality dawns and you find out whether cash flow generation and an acceptable margin structure for investors can be accomplished. This is probably the hardest of the three pieces to really get right. The somewhat classical approach to selling a new product is asking the "So what?" question, which invariably looks at whether your product is better or cheaper than current alternatives. Of course this is simplistic, but nonetheless it's a good start when developing a value proposition and planning how to communicate it. This article can't do justice to all of the considerations and planning that go into the sales process, but they are summarized in Figure 2.

Developing a value proposition is a multifaceted challenge, and recognizing your strengths and weaknesses should be central to developing a sales and marketing strategy. The first question we asked ourselves was, "Are we demand creators or demand fulfillers?" Needless to say, as a natural products supply chain management business we are a fulfillment-focused organization. Therefore, we immediately looked for strategic marketing, sales, and distribution partners who would grow demand for us to fulfill.

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Omega-3s are called "essential" fatty acids because they are vital for metabolism, yet the human body cannot manufacture them on its own, so they must be obtained from dietary sources. However, not all sources of omega-3 fatty acids are created equal. The following chart compares various plant and marine sources to fish oil.

Sources of Omega-3 Fatty Acids →	Fish oil	AHIFLOWER™ oil	Echium oil	Blackcurrant and hemp oils	SDA-enhanced soybean oil	Flaxseed oil	Microalgae oil	Krill oil
Environmentally Sustainable	?	✓	✓	✓	✓	✓	✓	-[1]
Non-genetically modified organism (non-GMO)	✓	✓	✓	✓	-	✓	✓	✓
Vegetarian and Vegan	-	✓	✓	✓	✓	✓	✓	-
No concerns for heavy metals, PCBs, or other toxins	-	✓	✓	✓	✓	✓	✓	-
Rich in GLA[2]	-	✓	✓	✓	✓	-	-	-
Produced under *Crop Assured 365®* system of identity preservation and quality assurance[3]	-	✓	✓	-	-	-	-	-
Pathway to EPA	EPA[4]	SDA[5]	SDA	SDA	SDA	ALA[6]	EPA	EPA
Contains >18% SDA	-	✓ One of the **richest** non-GMO plant-based sources of SDA known	-	-	✓	-	-	-

[1] Depletes a primary food source for marine animals.
[2] Gamma-linolenic acid (GLA), an omega-6 fatty acid
[3] *Crop Assured 365®* is Nature's Crops proprietary system of identity preservation and quality controls
[4] Eicosapentaenoic acid (EPA)
[5] Stearidonic acid (SDA). Approximately 20-30% of SDA converts to EPA in the body, or up to 5 times that of ALA.
[6] Alpha-linolenic acid (ALA). Less than 6% of ALA converts to EPA in the body.

Table 1. Comparison of omega-3 sources.

Delivering value to partners and stakeholders is vital; however, maximum value must ultimately be delivered to the consumer through the product and its identity. Ahiflower™ oil is the result of over 10 years of effort and investment. Self-affirmed Generally Recognized as Safe Status was achieved from the US Food and Drug Administration in 2013. In the European Union, novel food approval and New Dietary Ingredient processes are underway, with approvals anticipated in 2014. Table 1 summarizes the value proposition being communicated for Ahiflower™ oil.

Through a collaborative partnership model where the principle was "shared risk, shared reward," Ahiflower™ oil has gone from an idea to a commercial reality and will be featured as a retail branded product in North America in 2015. It presents a value-creating opportunity for multiple stakeholders from soil to oil and addresses the much-needed market challenge of finding a sustainable, scalable, safe, and efficacious solution to support the growth in demand for natural and cost-competitive omega-3 FA.

Fail fast, fail cheap

Contemplating how to avoid failure is equally important as determining how to be successful, and employing or investing in sound failure-avoidance strategies is a wise policy. Bringing a new crop product all the way through the supply chain only to find the market doesn't exist, the forecast prices aren't achievable, growers won't embrace its production, or the co-product fails to realize a sustainable value can signify the loss of years of research and development and the loss of millions of dollars. An accurate and realistic assessment of the market, its size, and price expectations matched by a robust business plan detailing the costs of building and managing a supply chain are the first investments to make.

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