Alternative markets for farmed Scottish shellfish and associated Requirements

> Work package 2 – market prospects for nutra/ pharmaceutical products

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## **Executive Summary**



## **Nutritional properties of bivalves**

Bivalves such as mussels and oysters are good sources of:

- Omega-3 EPA/DHA
- Potential anti-inflammatory agents (E and D resolvins)
- Protein (complete protein)
- Several minerals and vitamins
- Extraction of collagen is also possible from bivalves although not cost effective with current technologies

Of all bivalves, mussels are the most recognised source of nutraceutical/ pharmaceutical extracts thanks to decades of activity by the New Zealand greenlipped mussel (*perna canaliculus*) industry and there is a strong consumer association between green-lipped mussels and joint health.

However, the predominant species in the UK is the blue mussel (*mytilus edulis*) which is a much less researched species. Although the nutritional profile in many respects seems very similar to the green-lipped mussel, if the Scottish industry wishes to pursue opportunities in the nutra/ pharmaceuticals space, research will be required to establish whether the nutritional profile of the blue mussel also offers similar benefits for joint health, or any other health benefit.

Green-lipped mussel (*Perna canaliculus*)

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Blue mussel (Mytilus edulis)

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## **Extraction**

There are several methods of extraction currently utilised for bivalves globally:

**Freeze Drying/Lipholization after harvesting:** the mussels are removed from their shells and powdered in a purpose-built extraction plant. The mussel meat is freeze dried to ensure the stability of the nutrient content.

**Snap Drying in a drying operation:** liquid, slurry, or puree material is applied as a thin layer onto the outer surface of revolving drums that are internally heated by steam to dry the product

**Flash Drying/ Spray Drying Flash:** dry processing uses fresh uncooked mussel meat mixed in a liquid suspension. Particles of the mussel meat are sprayed into a current of hot air, and then evaporated to create a nutrient rich mussel powder.

Supercritical carbon dioxide (ScCO2) extraction Oil Extraction (or Supercritical Fluid Extraction): separating an active component (the extractant) from another (the matrix) using supercritical fluids.

**HPP processing**: MacLab in New Zealand has developed a high-pressure processing (HPP) technology to extract the mussel meat from the shell without using heat.

The lack of extraction facilities in Scotland, or even the wider UK, is a significant barrier to the development of a viable bivalve nutra/ pharmaceuticals industry here.

## **Dietary supplements**

- US 2019: Glucosamine and chondroitin are traditional go-to supplements for joint health, and products featuring this popular ingredient combination have a 57.8% share of the joint health segment and the highest dollar volume of the segment's sales, according to SPINS data.
- Despite their popularity, they have shown consistent decline over the last three years as the market diversifies with more options to address joint support.
- There are many dietary supplements for humans and for animals which features green-lipped mussel as a signature ingredient for joint health
- Awareness of green-lipped mussel for joint health is particularly high among pet owners where communications via health care professionals and retails channels have been particularly strong in recent years – the marketplace is also significantly less "noisy" with fewer brands and ingredients competing for consumer attention



## **Lessons from New Zealand**

New Zealand has pioneered the development of the nutra/ pharmaceutical market for bivalve extracts with their green-lipped mussel industry and there are a number of lessons that Scotland can take from their example:

- 1. Focus on nutra/ pharmaceutical routes as a value-added industry in its own right
- 2. Integrated supply chains, from primary products through to extraction and final product
- 3. Significant investment in research over a long period
- 4. Collaboration in research, marketing and communications
- 5. Strong industry bodies providing a focus for development, communications and funding
- 6. Investment in development of extraction techniques which have enabled the extraction of highest quality compounds.

## 1. Nutrition overview of mussels and oysters



Bivalves such as mussels and oysters are good sources of:

- Omega-3 EPA/DHA
- Potential anti-inflammatory agents (E and D resolvins)
- Protein (complete protein)
- Several minerals and vitamins



## In the UK:

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• Mussel production is primarily Blue Mussels (*Mytilus edulis*).



 Existing Oysters can be Pacific Oyster (Crassostrea gigas), Native Oyster (Ostrea edulis) and Kumamoto Oyster (Crassostrea sikamea).



### **Nutrition Facts per 100g of raw Oysters vs Mussels:**

	Oysters	Mussels
Energy (kcal)	65 - 81	74 - 86
Protein (g)	9,45 - 10,8	11,9 - 12,1
Fat (g)	1,3 - 2,3	1,8 - 2,24
Polyunsaturated (g)	0,4	0,6
Monounsaturated (g)	0,2	0,3
Saturated (g)	0,2	0,4
Carbohydrates (g)	4,9	2,5 - 3,7
Sugars (g)	Trace	Trace
Vitamins		
Vitamin A (µg)	75	0
Vitamin E (µg)	0,9	0,5 - 0,7
Thiamin B1 (mg)	0,06 - 0,2	0,1
Riboflavin B2 (mg)	0,2	0,21 - 0,4
Niacin (mg)	1,8	1,6
Vitamin B6 (mg)	0,05 - 0,2	0,05 - 0,1
Vitamin B12 (µg)	17	12 - 19
Folic acid (µg)	0	37

NewNutrition Business Source: "The Nutritional Benefits of Shellfish" report by the Shellfish Association of Great Britain, USDA © New Nutrition Business

### **Nutrition Facts per 100g of raw Oysters vs Mussels:**

	Oysters	Mussels
Minerals		
Sodium (mg)	510	290
Potassium (mg)	260	320
Calcium (mg)	140	26 - 38
Magnesium (mg)	22 - 42	23 - 34
Phosphorus (mg)	162 - 210	197 - 240
lron (mg)	5,7	3,9 - 5,8
Copper (mg)	7,5	0,2
Zinc (mg)	59,2	2,5
Chloride (mg)	820	460
Selenium (µg)	0	51
lodine (µg)	60	140

Source: "The Nutritional Benefits of Shellfish" report by the Shellfish Association of Great Britain, USDA

### Nutrition Facts per 100g of cooked Green-Lipped Mussels (Perna canaliculus) vs Blue Mussels (Mytilus edulis):





	Green-lipped Mussels	Blue Mussels
Energy (kcal)	105	172
Protein (g)	18,8	24
Fat (g)	3,1	4
Calcium (mg)	173	33
Omega-3 Fatty-acids (mg)	850-900	850-900
Copper (mg)	0,19	0,1
Iron (mg)	10,9	6,7
Magnesium (mg)	82,5	37
Manganese (µg)	898	680
Niacin (mg)	5,6	3
Phosphorus (mg)	330	285
Selenium (µg)	75,6	89.6
Zinc (mg)	16	2.7

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## Mussels and Oysters have the highest content of PUFA, EPA and DHA when compared to other Molluscs:





### Although lower in protein than other animal foods, mussels may be a more sustainable animal source of protein.

- Whilst mussels have a similar protein content per 100 g of edible portion to tofu, the protein content per kilojoule is better in mussels (22 g of protein per 600 kJ in mussels vs. 15 g of protein per 600 kJ in tofu). This means that mussels can deliver more protein in less energy besides being a complete protein.
- It is well understood how mussel derived protein stimulates muscle protein synthesis it is not yet known how much mussel protein is required to optimise muscle growth.
- Mussel protein also has a lower number of Green House Gas emissions in kgCO<sub>2</sub> per kg of edible product when compared to other animal protein.



#### Protein content per 100g of cooked and edible product:

**Available amino acid profiles for Pacific oysters** (*Crassostrea bilienata*) **and Asian green-lipped mussels** (*Perna viridis*) **show that both bivalves are a good source of essential amino acids**.





Source: Chakraborty, K., & Joy, M. (2020). High-value compounds from the molluscs of marine and estuarine ecosystems as prospective functional food ingredients: An overview. Food research international (Ottawa, Ont.), 137, 109637.

2. Mussel extracts and compounds relevant to pharma/ nutraceuticals



- Studies looking at bivalves like mussels and oysters have been increasing, but not all focus on these species' potential health properties and chemical components.
- In 2019, only 0.4% of molluscan species had been chemically analysed.
- For comparison, the volume of research on salmon is significantly higher.
- The evidence supporting health benefits of mussel-based supplements or extracts is limited and sometimes inconsistent.



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Published scientific articles mentioning mussels vs oysters vs salmon:

Bivalves offer a source of different compounds with potential health effects (anti-inflammatory, anti-viral, antioxidant, antihypertensive...) that can be relevant to both pharma and nutraceuticals.

Comparison of number of reports on various pharmacological properties of major mollusc species:



Source: Chakraborty, K., & Joy, M. (2020). High-value compounds from the molluscs of marine and estuarine ecosystems as prospective functional food ingredients: An overview. Food research international (Ottawa, Ont.), 137, 109637.

#### Bivalves with reported in vitro anti-inflammatory and immunomodulation potency:

Species	Family	Common name	Bioactivity(ies)	Reference(s)
Perna canaliculus	Mytilidae	New Zealand green-lipped mussel; New Zealand mussel; greenshell mussel; kuku; kutai	Inhibition of leukotriene production; inhibition of PGE2 generation; inhibition of lipoxygenase products in Arachidonic acid pathway; inhibition of cholesterol, COX2, TNF-α, and PGE biosynthesis; antioxidant potency; antiplatelet aggregation potency; fibrinolytic potency; inhibition of TNF-α and IL-1 generation; reduction in neutrophil superoxide burst activity; reduction in IgG biosynthesis; reduction in IL-2 and IL-6 generation; inhibition of COX-1 and COX-2 cyclooxygenase activity	Cheras et al. (2005a,b); Lawson et al. (2007); Mani and Lawson (2006); Treschow et al. (2007); Whitehouse et al. (1997)

#### Bivalves with reported in vivo anti-inflammatory effect:

Species	Family	Common name	Bioactivity(ies)	Reference(s)
Perna canaliculus	Mytilidae	New Zealand green-lipped mussel; New Zealand mussel; greenshell mussel; kuku; kutai	Inhibited adjuvant-induced arthritis; efficient reduction in footpad edema; significantly reduced incidence, onset and severity of collagen-induced arthritis in rats; significant reduction in overall arthritic scores, and scores for joint pain and joint swelling; reduction in neutrophils infiltration; reduction in rear paw thickness as well as inflammatory score in the fore paw; reduction in loss of bodyweight, crypt area losses, and cecum and colon weight; suppression of inflammatory mediators	Bierer and Bui (2002); Lawson et al. (2007); Li, Fu, Zheng, and Li (2014); Miller et al. (1993); Miller and Ormrod (1980); Tenikoff, Murphy, Le, Howe, and Howarth (2005); Wakimoto et al. (2011); Whitehouse et al. (1997); Whitehouse, Roberts, and Brooks (1999)
Perna viridis	Mytilidae	Asian green mussel	and proinflammatory cytokines production; promotion of anti-inflammatory cytokines generation Significantly reduced histamine-induced edema; significant reduction in carrageenan-induced edema; inhibition of formalin-induced inflammation; inhibition of dextran-induced paw edema	Chakraborty (2012); Sreejamole, Radhakrishnan, and Padikkala (2011)

Source: Khan, B.M. and Liu, Y. (2019), Marine Mollusks: Food with Benefits. Comprehensive Reviews in Food Science and Food Safety, 18: 548-564.

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В	usir	nes	SS		

### 1. Omega-3 Fatty Acids DHA/EPA

- Farmed mussels have 300–800 mg of omega-3 fatty acids per 100 g of cooked meat and 50– 60% of the lipid in mussel is phospholipid, meaning that omega-3 fatty acids are highly bioavailable.
- Omega-3 fatty acids have been shown to have multiple health benefits, from promoting brain health, to improving risk factors for heart disease, omega-3 from mussels has been mostly studied for its anti-inflammatory properties that help manage inflammation and reduce the pain and swelling associated with arthritis and other painful joint conditions, hence may improve bone and joint health.



Sources: Statistics of the USDA, 2019, Carboni S. et al. Mussel Consumption as a "Food First" Approach to Improve Omega-3 Status June 2019, Nutrients, 11(6), 1381(6)

### 1. Omega-3 Fatty Acids DHA/EPA

- A study by Stirling University investigated the impact of introducing mussels as a protein source in the lunchtime meal three times per week for two weeks on the omega-3 status of 12 participants.
- Each participant received a personalised lunch constituting one-third of their typical daily calorie consumption with ~20% of the calories supplied as cooked mussels. A portion of cooked mussels from each feeding occasion was tested for total omega-3 content.
- Blood spot analysis revealed a significant increase in the omega-3 index and whole blood EPA content during the study.
- Consuming mussels three times per week for two weeks as the protein source in a lunchtime meal is sufficient to moderately improve the omega-3 index and whole blood DHA + EPA content in young healthy adults.

Sources: Carboni S. et al. Mussel Consumption as a "Food First" Approach to Improve Omega-3 Status June 2019,, Nutrients, 11(6), 1381(6)

% weight of whole blood fatty acids as combined EPA, DHA and DPA in W1 vs W4:





### 2. Glycosaminoglycans (Chondroitin sulfates)

Glycosaminoglycans (GAGs) are principal components of cartilage and the synovial fluid found in joints. Cartilage is continually broken down and rebuilt in response to the stress placed on the joint. Enzymes secreted by the chondrocytes work to degrade collagen, which is then rebuilt. Proper collagen turnover, including adequate synthesis, is key to proper joint health and function.

5 GAGs that have relevance to connective tissue are:

- Chondroitin-4-sulfate & Chondroitin-6-sulfate
- Keratin sulfate
- Dermatan sulfate
- Hyaluronic acid

The principle function of GAGs is to increase lubrication of the joint and provide shock-absorption via incorporation of water molecules into the matrix. They help promote flexibility and elasticity within the joints. The severity of arthritis symptoms is directly related to the loss of GAGs within the joint and surrounding cartilage.

#### Amounts of crude glycosaminoglycans per 1g of dry sample of different shellfish:

Shellfish	Crude GAG <sup>a</sup> (mg)
M. chinensis	11.8
R. philippinarum	12.3
P. sachalinense	0.9
C. japonica	9.2
C. nippona	2.4
C. gigas	4.9
N. intersculpta	2.8
T. cornutus	3.5
S. broughtonii	25.9
M. yessoensis	8.0
M. galloprovincialis	3.2

### 2. Glycosaminoglycans (Chondroitin sulfates) in Green Lipped Mussels

Perna canaliculus provides a source of glycosaminoglycans, about 11-15% of dry weight of chondroitin sulfate.

The exact mechanisms by which Perna canaliculus works on arthritis is not yet clearly understood. Perna contains a unique combination of biologically active proteins, minerals, glycosaminoglycans (chondroitin sulfates), amino acids, nucleic acids and essential fatty acids which may yield a synergistic effect that promotes repair of the articular cartilage and reduces further deterioration of the joint.

Composition of Perna canaliculus			
-	P	ercentage Range	
and the second second	Protein (amino acids)	60-62%	
And the second	Carbohydrates	12-14%	
	Glycosaminoglycans (chondroitin sulfa	tes) 11-12%	
and the second s	Lipids	4-5%	
	Minerals	4-6%	
	Water	3-4%	

Sources: New Research and a Clinical Report on the Use of Perna Canaliculus in the Management of Arthritis By Roger V. Kendall; GreenLippedMussel.NZ, Okamoto, Y., Higashi, K., Linhardt, R. J., & Toida, T. (2018). Comprehensive analysis of glycosaminoglycans from the edible shellfish. Carbohydrate polymers, 184, 269–276.

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## 2. Glycosaminoglycans (Chondroitin sulfates) beneficial effects on arthritis

Limited clinical studies have shown that Perna canaliculus mussel can improve joint lubrication, reduce inflammation and joint pain and improve the mobility and range of motion of affected joints. Potential factors may explain these beneficial effects:

• Perna provides the necessary building blocks to rebuild damaged cartilage: amino acids, chelated minerals, glucosamine and glycosaminoglycans (GAGs).

- Exerts an anti-inflammatory/analgesic effect.
- Contains protein complexes and chondroitin sulfates that may inhibit enzymatic breakdown of the cartilage and connective tissue.
- Causes reduction in apoptosis response that may indicate a decrease of wayward cells contributing to the destructive cycles of arthritis.
- Contains an anti-histamine factor and prostaglandin inhibitors that reduce inflammation.
- Provides extremely valuable Omega-3 which inhibits the cyclooxygenase and lipoxygenase pathways in which leukotrienes and other inflammatory agents are produced.

Sources: New Research and a Clinical Report on the Use of Perna Canaliculus in the Management of Arthritis By Roger V. Kendall; GreenLippedMussel.NZ, Okamoto, Y., Higashi, K., Linhardt, R. J., & Toida, T. (2018). Comprehensive analysis of glycosaminoglycans from the edible shellfish. Carbohydrate polymers, 184, 269–276.

## **Green Lipped Mussels & bone health**

The first association between Green Lipped Mussel and bone health started in the 70s and was based on the observation that the Maoris population in New Zealand, whose diet was rich in mussels, were less likely to suffer from joint disease problems.

Since then, several cellular, animal and human studies have been done looking at the potential effect of Green Lipped Mussels on bone health, particularly arthritis and joint health, but further research is needed, and some studies have serious limitations (such as lack of control/placebo group).

#### Examples of clinical trials on Green Lipped Mussels and bone health:

Title & authors	Summary
'A randomized double-blind placebo-controlled trial to investigate the effectiveness and safety of a novel green lipped mussel extract - BioLex® -for managing pain in moderate to severe osteoarthritis of the hip and knee'. Stebbings, S. et al.	A double-blind, placebo-controlled study by the University of Queensland's Medical School evaluated the efficacy of GLM supplementation in 80 patients with severe arthritis of the hip and knee. Half the participants were prescribed GLM and the remaining half was given a placebo. Within eight weeks, the <b>patients taking the Green Lipped Mussel supplement had reported a</b> <b>noticeable improvement in joint mobility and a reduction in Paracetamol</b> <b>use.</b> The placebo group reported no change.
'Clinical efficacy and safety of Lyprinol, a patented extract from New Zealand green- lipped mussel (Perna Canaliculus) in patients with osteoarthritis of the hip and knee: a multicenter 2-month clinical trial' S. H. Cho. et al	A study published in the European Journal of Clinical Immunology showed that <b>80% of patients experienced an improvement in arthritis pain after taking Green Lipped Mussel.</b> 60 patients with symptomatic arthritis of the hip and knee were prescribed Green Lipped Mussel supplements for eight weeks. After four and eight weeks, 53% and 80% (respectively) of patients reported a significant reduction in pain and improvement in joint function.
'Perna canaliculus Lipid Complex PCSO-524™ Demonstrated Pain Relief for Osteoarthritis Patients Benchmarked against Fish Oil, a Randomized Trial, without Placebo Control' Zawadzki, M. et al.	A study in the journal Marine Drugs compared the efficacy of Green Lipped Mussel and Omega 3 Fish Oil in managing pain in 50 patients with osteoarthritis. After 12 weeks, the patients prescribed fish oil reported no improvement in symptoms, while the <b>patients prescribed Green Lipped Mussel reported a</b> <b>significant reduction in pain, as well as an improvement in joint mobility</b> <b>and movement.</b>

### 3. Phytosterols

Mussels are a source of cholesterol lowering phytosterols.

Phytosterols are cholesterol like compounds which form a key component of plant cell membranes. Thus, phytosterols are found in almost all plant foods but are particularly high in plant-based oils. Due to their similarity to cholesterol, phytosterols inhibit the absorption/reabsorption of dietary cholesterol/bile cholesterol and as a result can lower serum cholesterol levels.

As filter feeders, mussels consume algae and thus accumulate phytosterols in their edible parts. Analysis of Tasmanian Blue Mussels and New Zealand Green Lipped Mussels has demonstrated that they each contain 20 different phytosterols.



### 3. Phytosterols

#### Are mussels capable of altering blood lipids?

One study suggests that this is a possibility. Animal (meat, dairy, eggs) protein in the diet of healthy men was replaced with protein from mussels for a 7-day period.

They found that switching to protein derived from mussels significantly inhibited cholesterol absorption and improved the blood lipid profiles of already normolipidemic men.

VLDL triglycerides and VLDL cholesterol were significantly lowered when compared to the control diet and the LDL:HDL ratio was significantly reduced suggesting that mussels, as the sole protein source, can positively impact blood lipid profiles.

There is no way of knowing from this study if it was a component in the mussels such as the phytosterols or omega-3 fatty acids that led to the changes in blood lipids, or simply the reduction in dietary fat due to the removal of land-based animal products.

Another study concluded that cholesterol absorption was lower during the oyster/clam diet than during the chicken or crab diet periods. Total plasma cholesterol and triglycerides, VLD lipoprotein cholesterol and triglycerides, and low density and HDL cholesterol were not significantly different between any of the diets.

Sources: Childs, M. T., Dorsett, C. S., Failor, A., Roidt, L., & Omenn, G. S. (1987). Effect of shellfish consumption on cholesterol absorption in normolipidemic men. Metabolism: clinical and experimental, 36(1), 31–35; Childs, M.T.; Dorsett, C.S.; King, I.B.; Ostrander, J.G.; Yamanaka, W.K. Effects of shellfish consumption on lipoproteins in normolipidemic men. Am. J. Clin. Nutr. 1990, 51, 1020–1027.

### 4. Collagen

Byssal threads of mussels are almost entirely composed of proteins and produced by a specified organ, the mussel foot. Byssal threads are composed of over 50% collagen, although differences in concentration have been shown between species. Byssal collagens have no match with any known collagen sequence, its extraordinary properties include:

- High melting temperature
- Lack of banding patterns
- Some resistance to denaturants, acids and proteases which is an advantage when compared to collagen from fish wastes (skin, bones and scales) which has a low denaturation temperature and variable composition limiting its applications

The byssus comprises three distinct collagen proteins termed PreCols, surrounded by matrix proteins that differ significantly between the distal and proximal section:

- In the distal section of *Mytilus galloprovincialis*, 96% of the protein content is collagenous with tightly packed and straightly aligned fibrils predominantly made of the collagen PreCol-D, providing stiffness to the thread.
- The overall collagenous content in the proximal section is much lower, with matrix proteins representing 34% of the dry weight

Source: Suhre, M., Gertz, M., Steegborn, C. et al. Structural and functional features of a collagen-binding matrix protein from the mussel byssus. Nat Commun 5, 3392 (2014); Rodríguez, F., Morán, L., González, G., Troncoso, E., & Zúñiga, R. N. (2017). Collagen extraction from mussel byssus: a new marine collagen source with physicochemical properties of industrial interest. Journal of food science and technology, 54(5), 1228–1238.

### 4. Collagen

- Mussels have a lower protein content when compared to other animal sources of protein, hence, it is likely that to obtain relevant quantities of extracted collagen it will be necessary a high volume of mussels' byssus.
- However, besides being a complete protein, mussels' protein has a lower number of Green House Gas emissions in kgCO<sub>2</sub> per kg of edible product when compared to other animal protein.



Protein content per 100g of cooked and

edible product:

#### Essential amino-acid (g/100g protein) in mussel byssus vs pepsin-soluble collagen extracted from mussel byssus

Aa	Mussel byssus	PSC extract*
Thr	3.3	3.8
Val	3.0	4.4
Met	0.7	5.4
lle	2.6	3.8
Leu	1.1	5.6
Tyr	2.5	3.2
Phe	1.9	3
Arg	5.8	9.2
Lys	1.7	6.2
His	2.7	1.9

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# 3. Extraction methods and how these impact on nutritional quality



## Extraction methods currently used for Green Lipped Mussel (I)

Normal processing of mussel extracts by using steam-based and other conventional methods denatures much of the mussel bioactive compounds associated with anti-inflammatory activity. That's why the development of cold processing techniques was so important for processing components of the mussel extracts.

Currently, a range of extraction processes are used to produce mussel extracts and raw ingredients for existing pharma and nutraceutical products.

Deep Blue Health is a New Zealand that offers a range of dietary supplements, some of which using Green Lipped Mussels. The company details its extraction processes, which claims to "be designed to preserve nutrient content, ensuring that our products contain the highest levels of Omega 3 Fatty Acids, Glycosaminoglycans and Chondroitin":

1. Freeze Drying/Lipholization after harvesting: the mussels are removed from their shells and powdered in a purpose-built extraction plant. The mussel meat is freeze dried at a controlled temperature to maintain the integrity of the bioactive compounds and ensure the stability of the nutrient content.



Sources: Khan, B.M. and Liu, Y. (2019), Marine Mollusks: Food with Benefits. Comprehensive Reviews in Food Science and Food Safety, 18: 548-564; Deep Blue Health

## **Extraction methods currently used for Green Lipped Mussel (II)**

- 2. Snap Drying in a drying operation: liquid, slurry, or puree material is applied as a thin layer onto the outer surface of revolving drums that are internally heated by steam. After about three-quarters of a revolution from the point of feeding, the product is dried and removed with a static scraper. The dried product is then ground into flakes or powder. Drum drying is one of the most energy efficient drying methods. Snap drying (drum drying) is faster than freeze drying and also locks in more nutrients. Importantly, it minimises the key risk factors that can impact the quality of Green Lipped Mussels powder, including enzymatic degradation and exposure to excess heat and air.
- 3. Flash Drying/ Spray Drying Flash: dry processing uses fresh uncooked mussel meat mixed in a liquid suspension. The process begins by spraying particles of the mussel meat into a current of hot air, creating a mist of fine droplets. The moisture in the droplet particles is evaporated in nano seconds to create a nutrient rich mussel powder.
- 4. Supercritical carbon dioxide (ScCO2) extraction Oil Extraction (or Supercritical Fluid Extraction): the process of separating an active component (the extractant) from another (the matrix) using supercritical fluids. It is the most effective and efficient way to extract bioactive ingredients. Green Lipped Mussel supplements produced using oil extraction are claimed to be "significantly higher potency than supplements produced via Freeze Drying or Snap Drying, meaning much lower doses are required to produce a therapeutic benefit".

Sources: Khan, B.M. and Liu, Y. (2019), Marine Mollusks: Food with Benefits. Comprehensive Reviews in Food Science and Food Safety, 18: 548-564; Deep Blue Health

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## Manufacturing process for Green Lipped Mussel based dietary supplements:

Manufacturing Process for Green Lipped Mussel





Sources: Deep Blue Health

## **Extraction methods currently used for Green Lipped Mussel (III)**

- Biolane GLME is a NZ Green Lipped Mussels extract that can be used in both human dietary supplements and pet food/supplements.
- It goes through a freeze-drying process, which "ensures the retention of nutrients found in the native green-lipped mussel".
- 1) Harvest: The mussels reach peak condition at around 18 months of age. They are harvested and shipped in refrigerated trucks to the factory.
- 2) Centrifuge: They are transferred to cool storage and processed through centrifugation, where the mussels are crushed and placed into a centrifuge, separating meat from shell.
- 3) Freeze-dry: The liquid extract is immediately transferred to trays and snap frozen. This is in preparation for freeze drying at -20 Celsius degrees.
- 4) Milled: The dry extract is milled to produce a fine powder.



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## Extraction methods currently used for Green Lipped Mussel (IV)

Maclab is a biotechnology company that extracts bioactives from NZ Green Lipped Mussels for the biopharmaceutical industry.

MacLab developed and patented a stabilisation process that protects the bioactive anti-inflammatory activity from degradation. This involves high-pressure processing (HPP) technology to extract the mussel meat from the shell without using heat.

HPP is a technique used in the food industry for non-thermal pasteurisation. The process ensures the product remains fresher and keeps the same nutrient profile that was present prior to the pasteurisation process.

Another important scientific development that Maclab patented was the  $CO_2$  extraction technology, which enables the bioactives to be extracted from the powder without any chemical solvent residue, unlike cheaper solvent extraction methods.

## MacLab

Sources: MacLab


## Extraction methods currently used for Green Lipped Mussel (V)

The norm when manufacturing Green Lipped Mussel Powder is to not use any heat or steaming during manufacturing, this assures that nutrient levels are not destroyed. But some companies do use this as a selling point.

Trade Ingredients described its manufacturing process of Green Lipped Mussel Powder:

- 1) Mussels are shucked into mussel meat, de-fatted and crushed into slurry.
- 2) Mussels are poured into trays and frozen within 24 hours.
- 3) Frozen mussel slurry trays are freeze dried into a dry biscuit.
- 4) Super critical fluid extraction is applied to remove the surface lipids (3-4%)
- 5) Mill into a powder.







## Collagen extraction methods used for Chilean mussels

- Mussel byssus is a by-product of mussel production and is a potential source of collagen.
- A study extracted collagen from the byssus of Chilean mussel using an enzymatic pepsin-aided extraction method was employed. This enzymatic hydrolysis was done at two pepsin/substrate ratios (1:50 or 4:50) and times (4 or 24 h). Extraction was conducted at 80°C for 24 h, in a 0.5 N acetic acid solution.
- Hydrolysis time had significant effect on collagen content, hydroxyproline content and extraction yield. Hydrolysis with a pepsin/byssus ratio of 4:50 for 24 h gave the better extraction performance with values of 69 mg/g protein, 1.8 mg/g protein and 30%, for collagen content, hydroxyproline content and extraction yield, respectively.
- No differences were found for the viscosity and surface tension of collagen dispersions, suggesting that the enzymatic hydrolysis did not affect the integrity of the collagen molecule.
- Denaturation temperature of freeze-dried byssus collagen presented a high value (83–91 ° C), making this kind of collagen a very interesting material for encapsulation of bioactive molecules and for biomedical applications.
- The highest collagen (68.6 mg/g protein) and hydroxyproline content (1.84 mg/g protein) were obtained for the hydrolysis treatment at a pepsin:byssus mass ratio of 4:50 for 24 h,

Source: Rodríguez, F., Morán, L., González, G., Troncoso, E., & Zúñiga, R. N. (2017). Collagen extraction from mussel byssus: a new marine collagen source with physicochemical properties of industrial interest. Journal of food science and technology, 54(5), 1228–1238.

# Collagen extraction methods used for Chilean mussels

A Extraction method of collagen from mussel byssus by using the enzymatic extraction procedure



**B** Critical physiological steps in the extraction process of collagen from byssal thread

Source: Rodríguez, F., Morán, L., González, G., Troncoso, E., & Zúñiga, R. N. (2017). Collagen extraction from mussel byssus: a new marine collagen source with physicochemical properties of industrial interest. Journal of food science and technology, 54(5), 1228–1238.

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# 4. Mussels in dietary supplements & food ingredients



## 4.1 Market size



### **Dietary supplements market**

- Energy and weight management application segment led the market and accounted for a revenue share of 29.5% in 2020.
- In the US, the dietary supplement market value was over US\$36 bn in 2020.
- Tablets and capsules accounted for over 50% of the market in 2020



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### © New Nutrition Business

Source: www.grandviewresearch.com

### **Dietary supplements regional shares**

- North America emerged as a leading regional market with a revenue share of 35.7% in 2020 on account of the growing use of products with high nutritional value and low-calorie content. Furthermore, United States Holds The Major Share In North America Bone And Joint Supplement Market
- Asia Pacific is expected to witness significant growth over the forecast period. The market is expected to be the largest regional market by 2028 owing to the growing consumer base in the countries, including India, China, and South Korea. Increasing expenditure on health-enhancing products in the region owing to growing per capita income and increasing awareness is expected to drive the demand for dietary supplements over the forecast period.
- The European region accounted for a significant revenue share in 2020 and is expected to expand at a CAGR of 6.8% over the forecast period. Higher consumer awareness and higher per capita disposable income in the developed countries, like France, Germany, and the U.K., are expected to drive the regional market over the forecast period.

# Dietary supplements for bone and joint health

- US 2019: **Glucosamine and chondroitin** are traditional go-to supplements for joint health, and products featuring this popular ingredient combination **have a 57.8% share of the joint health segment** and the highest dollar volume of the segment's sales, according to SPINS data.
- Despite their popularity, they have shown consistent decline over the last three years as the market diversifies with more options to address joint support.
- Products indicated for joint health and marketed primarily for either ingredient or the combination of the two declined 5.7% over the past year to US\$181.9 million, according to SPINSscan Natural and Specialty Gourmet Channels and SPINSscan Conventional Multi Outlet (powered by IRI) in the 52 weeks ending May 1, 2019. This was after falling 6.8% in the year ending May 2018 and 7.9% in the year ending May 2017. Newer players in the segment have wider applications beyond joint support, and, as consumers become more educated around using food and supplements in their own self-care, they are choosing products that serve multiple purposes.
- In addition to a greater variety of ingredients to address joint health, delivery methods are diversifying. Tablets are still going strong as the top delivery method in joint health supplements, growing 4.2% over the past year to \$96.8 million. Sales for other common delivery methods, including capsules, caplets and liquid supplements, however, all showed double-digit decline as newer powdered supplements increase in popularity, growing 9.5% to \$4.7 million. Powdered products such as collagen and bone broth are driving the growth and giving consumers flexibility of dosage and convenience, mixing easily into food and drinks and continuing to blur the line between functional food and supplements. Pellets also saw a modest increase that mirrors the growth of homeopathic remedies.

## **4.2 Consumer interest**



- Most online articles mentioning mussels are about recipes in Australia and New Zealand there is a decrease since 2016 in the number of articles on mussels.
- In the UK, US and New Zealand, there is an increase in the number of online articles mentioning mussels and health.



Online articles mentioning





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- Articles on "mussels + joints" have shown an increase in all markets since 2016, with the highest growth happening in the US, with 32% more articles in 2020 than in 2016.
- All articles specifically on joint health focus on Green Lipped Mussels.





Source: Google Advanced Searches

Research into potential joint and muscle

## Two of the biggest online health platforms in the US – WebMD and Healthline – have dedicated articles to green lipped mussels and its benefits.

The conclusion is similar: there's early research that show promising effects, but often studies are inconsistent, and more studies are needed for stronger recommendations.



### Uses & Effectiveness ()

#### **Insufficient Evidence for**

Business

- Asthma. Some early research shows that taking New Zealand green-lipped mussel extract decreases daytime wheezing and improves breathing in some people with asthma. Other early research shows that taking the extract reduces how much rescue medication is needed by people with persistent asthma. But using New Zealand green-lipped mussel extract does not seem to improve asthma symptoms in children.
- Attention deficit-hyperactivity disorder (ADHD). Early research shows that taking New Zealand green-lipped mussel extract doesn't help with hyperactivity, impulsiveness, or inability to pay attention in children with ADHD. But it might help children without ADHD who are very active or have problems with attention.
- Exercise-induced muscle soreness. Early research shows that taking New Zealand green-lipped mussel extract helps to prevent the muscle soreness that occurs a few days after a hard workout.
- Osteoarthritis. Most early research suggests that taking New Zealand green-lipped mussel extract by mouth reduces symptoms of osteoarthritis, including pain and stiffness. But not all research agrees.
- Rheumatoid arthritis (RA). Some early research suggests that taking New Zealand green-lipped mussel extract by mouth reduces symptoms of RA, including pain and stiffness. But not all research agrees.

### healthline

#### NUTRITION V Evidence Based

### **Green-Lipped Mussel Supplements:** All You Need to Know

Nutrient content | Anti-Inflammatory effects | Benefits | Supplement forms |
Safety & side effects | Bottom line

### The bottom line

Green-lipped mussels are native to New Zealand, where they're a staple food in the diets of the indigenous Māori people.

They're also popular as a supplement, as the mussels contain various anti-inflammatory nutrients, including omega-3 fatty acids and chondroitin sulfate. They also contain several vitamins and minerals.

However, only sparse and inconsistent evidence supports the use of green-lipped mussel supplements for inflammatory conditions like asthma, arthritis, DOMS, or ADHD in children.

Before trying a green-lipped mussel supplement, make sure it was produced using a method like freeze-drying, and consult your healthcare provider about the potential risk of negative side effects.

### **Consumer awareness...**

- Most consumers in the UK and other Western markets are aware of mussels as a seafood and associate it to culinary usage.
- More health-conscious consumers possibly connect general seafood benefits with mussels, but not necessarily the specific studied benefits so far.
- Consumers suffering from bone health issues and joint pain are the most likely to have heard about mussels' potential benefits for such conditions.



## 4.3 Industry activity



There was a global increase in dietary supplements launched with bone health claims in 2020. but Food & Beverage products have remained stable.

- Asia pacific is the most active region for F&B products, partly due to presence of the expert brand Anlene in the region, which has fuelled consumer interest and awareness of bone health in F&B formats.
- Europe is the most active region when it comes to dietary supplement launches.

Product launched with "bone health" claims

globally

Business

F&B launches with "bone health" claims per region in 2020





## In all 4 markets the number of dietary supplements launches with bone health claims has grown since 2016.

The same is not true for F&B products with bone health claims, as these have been decreasing in all markets except the UK where launches remain stable.



**Dietary supplements launched with** 

"bone health" claims

### F&B launched with "bone health" claims



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Source: GNPD Mintel

## There was a small increase in F&B products launched with omega 3 in 2020.

- Asia pacific and Europe are the most active regions for omega 3 F&B product launches, where infant formulas dominate.
- Europe is the most active region when it comes to dietary supplements launches.

Dietary supplements

F&B launches with "omega 3" per region in 2020





© New Nutrition Business

### Product launched with "omega 3" globally

F&B

Business

53

In all 4 markets the number of F&B launches with omega 3 has decreased in 2020.

Dietary supplements launches with omega 3 have increased in the UK and Australia & NZ.



### F&B launched with Omega 3

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Source: GNPD Mintel

## Dietary supplements with chondroitin are on the rise but still account for a small number of products launches yearly (<50).

There are almost no Food & Beverage products marketed as containing chondroitin.

Europe and North America are the most active regions.





In all selected markets the number of dietary supplements with chondroitin have increased in 2020, except in Australia and New Zealand where there was a decrease.

There were no launches of Food & Beverage products with chondroitin in any of the markets



## Chondroitin

**Dietary supplements launched with** 



Source: GNPD Mintel

## Both F&B products with phytosterols/ plant sterols and dietary supplements launches have decreased in 2020 globally.

There's almost no dietary supplements with phytosterols.

Europe and Asia are the most active regions.



There are few F&B products with phytosterols/ plant sterols in the selected markets, with total number of products launches being less than 10 per year per market.





Source: GNPD Mintel

Both dietary supplements and F&B with collagen have increased globally, with Asia dominating the F&B segment whereas Europe is the most active region when it comes to dietary supplements.



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# Both dietary supplements and F&B with collagen are on the rise across all selected markets, with the US leading in both supplements and F&B in 2020.





## 4.4 Companies/ product examples



## Commercially available mussel extracts in dietary supplements

- Most of the commercialized mussels' extracts are from New Zealand Green Lipped Mussels.
- The key benefit studied for these extracts and offered by the products that incorporate them is on joints health, connected to potential anti-inflammatory activity.
- Capsules, tablets and powders are the most common formats for products with mussels' extracts.

### Examples of commercially available mussels' extracts for dietary supplements and food applications:

Extract	Species	Potential benefits
Cadalmin	Perna viridis	Reduce chronic joint pain and arthritis Anti-inflammatory
Greenshell	Perna canaliculus	Anti-inflammatory Reduce joint pain and enhance mobility
Lyprinol	Perna canaliculus	Anti-inflammatory in osteoarthritis and rheumatoid arthritis
Biolane	Perna canaliculus	Suppress inflammation in arthritic joints and modify chronic immune responses

### Greenshell<sup>™</sup> Green Mussel extract

The New Zealand mussel industry developed the trademark **Greenshell**<sup>™</sup> ingredient, which is an extract from *Perna canaliculus* that has been shown to potentially reduce joint pain and enhance joint mobility.

It is asource of glycosaminoglycans, the significant components of cartilage, and synovial fluids in joints, as well as a source of DHA and EPA omega-3 fatty acids, along with 30 other essential fatty acids.



Source: Chakraborty, K., & Joy, M. (2020). High-value compounds from the molluscs of marine and estuarine ecosystems as prospective functional food ingredients: An overview. Food research international (Ottawa, Ont.), 137, 109637.



## **Case-study 1: Sea to Me (I)**

- New Zealand ingredient supplier company Sanford launched Sea to Me in 2018 as their own brand of dietary supplements with Greenshell<sup>™</sup> mussel powder.
- The company invested US\$13 million in a marine extracts center to produce a range of products, including Greenshell<sup>™</sup> mussel powder and oil. The company also invested in human trials to look at the ingredients' effect on inflammation management and muscle recovery.

### Key claims:

- Synergistic blend of Omega-3, lipids, amino acids and minerals.
- **Support your joint health:** Rich in Omega-3 and lipids, it also contain GAGs, sometimes called the glue of life, studies suggest they may benefit joint health.
- **Packed with nutrition:** Packed with protein and a natural source of selenium, calcium, iron, B vitamins, tyrosine, tryptophan and zinc. Mussels offer many of the building blocks of life, available as easy to absorb wholefood bioactives.

### Recommended usage:

Two daily capsules in the morning with breakfast, or at any time of the day.



**Ingredients:** 100% New Zealand Greenshell<sup>™</sup> Mussel, Vegetable Delayed-Release Capsule.

## **Case-study 1: Sea to Me (II)**

### Focus on traceability and sustainability

"We source our mussels sustainably – NZ mussel is regarded as one of the most well-managed fish stocks in the world. We also maintain a **very short supply chain**, from harvest to the time we convert the mussels into powder – the whole process takes less than 24 hours." – Andrew Stanley, Sanford's general manager of innovation



## Sustainable, traceable and proven.

Sea To Me prides itself on the fact that we grow, harvest, process and encapsulate our product before delivering it directly to you. This enables us to guarantee the highest quality and sustainability at every step of the process, and helps you understand what you're taking and where it came from.

From coast to capsule to you. Sea To Me creates Joint Mobility Support in the most sustainable, traceable and effective way.

"To minimize environmental impact, we have ensured that all of our packaging is curbside recyclable anywhere in NZ. Our bespoke **bottle is made from sugarcane plastic**, as sugarcane grows it removes carbon from the atmosphere. Sugarcane plastic bottles help to reduce your carbon footprint." - Sea to Me website

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## **Biolane<sup>®</sup> Green Mussel extract (I)**

Biolane® GLME is an extract from *Perna canaliculus* and has been on the market since the 70s.

### Key claims:

Business

"Contains several active components that help to suppress inflammation in arthritic joints and modify chronic immune responses:

- Biolane GLME inhibits the production of inflammatory prostaglandins and histamine. Reducing the swelling.
- Biolane GLME inhibits the accumulation of white blood cells, which are important mediators in tissue destruction."





### **Biolane<sup>®</sup> Green Mussel extract (II)**

### Main nutritional components of Biolane:

- **Protein:** Biolane<sup>®</sup> contains 1.7-2.4x more protein than Oyster extract. It contains rich amount of proteoglycan which works as a "cushion for joints".
- Amino acid composition: Biolane<sup>®</sup> contains a balanced amino acid composition. In comparison with Oyster extract, it contains 5x more lysine, 4,7x more leucine and methionine.
- **Glycosaminoglycan:** Biolane<sup>®</sup> contains high amount of glycosaminoglycan such as chondroitin sulfate and hyaluronic acid.

Biolane<sup>®</sup> has been studied for potential benefits for athletes, seniors, people suffering from bone health issues and animals such as horses and dogs:



Biolane is beneficial for relieving symptoms of non-arthritic sporting and athletic injuries



Biolane GLME as a solution for horses with chronic fetlock lameness attributed to osteoarthritis



Biolane is effective for osteoarthritis of the knee (Gonarthiritis)



## **Case-study 2: Kordel's Musseltone**

- The nutraceutical supplement Musseltone® for use against rheumatoid arthritis pain, by the dietary supplements brand Kordel's, contained Biolane<sup>™</sup> extract.
- Each 500mg tablet of Musseltone® contained a minimum of 45mg Mussel Lipids.
- However, this range of products is no longer available on their website and it's "out of stock" in online retailers.

### Key claims:

- Contains Biolane extract
- May help maintain joint mobility and flexibility of tendons, ligaments and connective tissue.
- Made using only peak condition, fresh, live, sustainably farmed mussels.
- Combined with glucosamine for maximum benefit.

### **Recommended usage:**

- An initial high dose of three 500mg tablets was recommended for up to three months before reducing to a maintenance of one - two daily.
- Benefits are usually obtained during this initial period. However, pain may worsen temporarily due to the Mussel Extract initial effect on the body.



### Ingredients:

Biolane green lipped mussel extract, microcrystalline cellulose, dicalcium phosphate, carboxymethyl cellulose, silicon dioxide, stearic acid, coating: hydroxypropylmethylcellulose, magnesium stearate.

## Lyprinol® Green Mussel extract

- Lyprinol is a lipid extract of *Perna canaliculus* which was patented for arthritis and asthma benefits.
- In a review article back in 2011 the conclusion is that Lyprinol does have anti-inflammatory effects in some animal models of inflammation, hence may have benefits in dogs with arthritis.
- There are design problems with the clinical trials of Lyprinol in humans as an antiinflammatory agent in osteoarthritis and rheumatoid arthritis, making it difficult to give a definite answer to how effective Lyprinol is in these conditions.
- The trademark for Lyprinol is held by Pharmalink.
- <u>Europe:</u> Lyprinol has been registered as a 'Special Food for Medical Purposes' in accordance with EU regulations.
- <u>USA:</u> Back in 2007 The Food and Drug Administration warned Lyprinol USA about their extravagant anti-inflammatory claims.



## **Case-study 3: Blackmores Lyprinol**

Blackmores is one of the biggest Australian dietary supplement's companies, offering a variety of vitamins, minerals, herbs and nutrients.

### Key claims:

- Reduces symptoms of mild arthritis
- Relieves inflammation
- Reduces symptoms of mild osteoarthritis
- Help maintain general health and wellbeing
- Non-GMO specialised NZ marine oil extract of greenlipped mussel

### Recommended usage:

- **Lyprinol:** recommended starting dose is 2 capsules twice a day with meals in the morning and evening, for up to 8 weeks. After 8 weeks take 1 capsule twice a day with a meal, or as professionally prescribed.
- **Lyprinol Double:** recommended starting dose is 1 capsule twice a day for up to 8 weeks. After the initial 8 weeks take 1 capsule once a day or as professionally prescribed. Take with food.



Active ingredient per capsule: 50mg Lyprinol (marine lipid PCSO-524 oil extract, Green lipped mussel oil)



Active ingredient per capsule: 100mg Lyprinol (marine lipid PCSO-524 oil extract, Green lipped mussel oil)

### **Green Lipped Mussel dietary supplements examples**

All products connect to bone health, joint care and mobility benefits.



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# 5. Mussels in sports nutrition products


# **Sports nutrition market size**

- The global sports nutrition market size was estimated to be over US\$60bn in 2020.
- There's an expected 8% CAGR increase between 2020-2024.

#### Sports nutrition market worldwide from 2018 to 2023

(in billion U.S. dollars)



NewNutrition Business Source: Statista, Business Wire © New Nutrition Business

# **Collagen market size**

- In 2019, the Collagen market was over US\$3.5 bn globally.
- It is expected to grow at a CAGR of 6-8% to reach US\$6 bn by 2026.





# **Collagen market profile**

Type: the collagen market is mainly segmented into gelatin, collagen peptide, native collagen, and synthetic collagen. In 2020, the gelatin segment is estimated to command the largest share of the overall collagen market. This large share is mainly attributed to the increased demand from food & pharmaceutical industries, owing to its outstanding stabilizing features and binding characteristics.

<u>Source</u>: the collagen market is segmented into bovine, porcine, fish, chicken, sheep, and other sources. In 2020, the bovine segment is estimated to command the largest share of the overall collagen market. This large share is mainly attributed to its several health benefits, such as skin health, tendon reinforcement, bone loss prevention, and arthritis relief.

<u>Application</u>: the collagen market is mainly segmented into food and beverage, pharmaceuticals, nutraceuticals, healthcare, cosmetics, and technical applications. In 2020, the healthcare and F&B segments accounted for the largest share of the overall collagen market.





#### Source: Research&Markets, Global Market Insights, Grand View research © New Nutrition Business

Products with collagen are on the rise, with ANZ leading the way, followed by Europe and the US – where consumption and launches of collagen products increased significantly in 2020.



Source: GNPD Mintel

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There are some products associating collagen with sports performance, but most collagen products is associated to skin, hair and nails benefits, followed by bone health.



Market: Spain

**Product:** Colagen Pro Sport 10 Powder with hydrolyzed collagen, aminoacids, L-glutamine taurine, chondroitin sulfate, vitamins, bamboo extract, d-glucosamine, chondroitin, bromelain, MSM, organic silicon and hyaluronic acid. It also contains vitamin C and vitamin B6, "which contribute to normal energy metabolism, and is enriched with proteins, which help increase muscle mass:.

**Ingredients:** hydrolyzed collagen (from fish), L-glutamine, chondroitin sulfate (fish), acidulant (citric acid), natural flavour, bromelain, glucosamine, L-taurine, calcium ascorbate (vitamin C), methylsulfonylmethane (MSM), bamboo dry extract (Bambusa bambos), hyaluronic acid, sweetener (sucralose), pyridoxine hydrochloride (vitamin B6)



Market: UK Product: SiS Performance Collagen Pre-Hab/Re-Hab Shot with 20g of collagen hydrolysate and 80mg vitamin C per serving, "which contributes to normal collagen formation and supports bone and joint health". The collagen hydrolysate is from bovine sources.

**Ingredients:** water, collagen hydrolysate, acidity regulator (malic acid, citric acid, phosphoric acid), natural flavouring, vitamin C (ascorbic acid), preservative (potassium sorbate), sweeteners (sucralose, steviol glycosides)

# In the US, Vital Proteins (now acquired by nestle) is helping to familiarize consumers with collagen and its benefits.

- Among its many collagen-based products, Vital Proteins offers "Marine Collagen" which is made from the scales of fresh, non-GMO, wild-caught white fish off the coast of Alaska.
- The brand claims it's "highly bioavailable, digestible and easily dissolves in hot and cold water."



NITAL PROTEINS MARINE DOLLAGEN Par Collagen per Seving Skin, Hair, Nail - Jorn Sport



Unflavored

**Dietary Supplement** 

NET WT 7.8 OZ (221 gl

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Vital Proteins has a dedicated range of products for sports nutrition – Vital Performance – combines collagen from bovine sources with other key ingredients in products for either pre or post workouts.









# ATHLETIC PERFORMANCE\*\*

Power from within starts with collagen that fuels your movement. Support your fitness journey - no matter what it looks like - with powders and drinks for every part of your workout.



#### © New Nutrition Business

Our three-phase system combines collagen with premium ingredients to help you conquer every movement.

Currently there are almost no products using collagen from mussels or even combining mussels and collagen on the same product. We found one example in the UK:



UK Dietary Supplement Power Health has a Green Lipped Mussel supplement which is combined with Hyaluronic Acid, Turmeric and Collagen and claims to "help maintain healthy joints, supporting flexibility and pain free joints".

Each tablet contains on average: 300mg of Green Lipped Mussel Powder, 100mg Turmeric, 5mg Hyaluronic Acid & 100mg of Collagen

**Ingredients:** Green Lipped Mussel Powder, Bulking Agent: Microcrystalline Cellulose, Turmeric Powder (Curcuma longa), Hyaluronic Acid, Collagen Powder, Anti-caking Agents: Polyvinylpyrrolidone, Fumed Silica, Magnesium Stearate.

# 6. Mussels in pet food products



# A rapidly growing sector

Petfood is currently one of the fastest-growing segments in the global food industry. According to Euromonitor, the petfood market was worth £67bn in 2018, but is forecast to grow to £102bn by 2024.

In the UK, pet food sales totalled £2.9bn in 2020, growing 16% since 2015. Volume sales also grew in that period, but only by 3%, reflecting the growing trend towards Premiumisation in the UK market.

Growth is particularly notable in China, where the petfood market was worth more than £5bn in 2019 and growing is growing by 30% per year. It is set to be 10% of the global market vs 1% a decade ago.

"Petfood will be the next infant formula in China – a boom sector" Pet food industry executive

Pet owners are very brand-loyal, meaning that to date there is very little white label penetration in the pet food market. Just 2 companies - Mars and Nestlé – dominate petfood globally, with a combined 45% market share.

Given the growth rates in the sector, other large multinationals have also recently shown interest in petfood – in 2018 General Mills acquired Blue Buffalo in the US for a reported \$8bn.

# Pets in the UK

There are over 34 million pets in the UK – 49% of households have at least one pet.

The COVID-19 pandemic has had a significant impact on pet ownership in the UK. 3.2 million households have acquired a pet since the start of the pandemic, and owners are becoming younger – 56% of new pet owners are aged 16-34.

2021 TOP TEN PETS		
12 MILLION DOGS	a a	
12 MILLION CATS	2	
1.3 MILLION INDOOR BIRDS	<b>*</b>	
1.2 MILLION DOMESTIC FOWL	Ý	
1 MILLION PABBITS	-	
800,000 GUINEA PIGS	@\$	
600,000 HAMSTERS	é	
500.000 HORSES & PONJES	<b>.</b>	
S00,000 PIGEONS	4	
400,000 TORTOISES & TURTLES	VID.	
Note: All figures are rounded to the nearest 100,000.		
5m INDOOR FISH TANKS (12% households)		🚔 ptme
4m OUTDOOR PONDS		PET FOOD MANUFACTUR



Source: Pet Food Manufacturers' Association Annual Pet Population Data

# Humanisation of pets

The main growth trend in pet care is Humanisation – that is owners trying to incorporate pets into more and more aspects of their human lives, like holidays, exercise, nutrition and health care with companies introducing new kinds of products and services to capitalise on this trend.

As a result, many of the trends that we see in the human food industry are mirrored in pet food:



42% of pet food buyers consider their pet a "foodie" according to Mintel.

Brands using human grade food, and homemade-style recipes featuring gourmet ingredients are growing significantly



Most major pet food brands now allow consumers to customise their pet's diet according to factors such as breed, age, energy levels and any health issues.

Online brands like Tails.com offer food tailored to the specific needs of individual pets



34% of UK dog food buyers believe it is good for pets to regularly have a plant-based meal instead of a meatbased one.

Flexitarianism for pets, reducing red meat consumption and adding vegetables and other plants to recipes, is on the rise

# Humanisation of pets

- The number of pet food products launched with "mussels" has been increasing steadily in recent years.
- Most active regions are Asia and Europe.
- Most products are part of a range of products that include other flagship ingredients and account for only a small part of the recipe.



#### Pet food products launched globally with "mussels"

## "Happy I Fit & We Food con ingredien sources 16% fat.

Germany

Interquell Happy Dog

"Happy Dog Supreme Fit & Well Sport Dog Food contains natural ingredients, five sources of protein and 16% fat. It is enriched with original New Zealand mussels and L-carnitine."

# **Chondroitin and Omega 3**

- The number of pet food products launched with "chondroitin" and "omega 3" increased in 2020.
- Most active regions are Asia and Europe.
- Most products don't specify the source of chondroitin but omega 3 is often listed as coming from mussels or salmon.







Source: GNPD Mintel

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# Mussels as a whole food or treat

There are a few brands who sell cooked and freeze dried mussels as a single product, aimed at cats or dogs.

In the UK, the Healthy Pet Store sells cooked mussels which can be mixed with other raw, wet or dry dog food or given individually as a health treat.

Given the trend towards humanisation in pet food, there is certainly scope for Scottish mussel producers and brands to develop this market further, possibly with product which is not suitable for the human retail market, but price will be key



Business

In Hong Kong, Northwest Naturals Raw-Rewards Freeze dried Green Lipped Mussels are sold as a topper for regular pet food and as a treat. The product contains 100% premium freeze dried mussels."

#### Price \$13.99 for 2oz (56.7g) (£179.37 per kilo)



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# **Mussels as a premium ingredient**

UK petfood brand Lily's Kitchen (now owned by Nestle Purina since 2020) uses mussels as a signature dish in selected cat food products. In these products, mussels are used as a gourmet ingredient, to provide visual appeal and texture rather than for any stated health benefit.

In 2020 UK sales for Lily's Kitchen increased 25.6% to £35.3m and non-UK by 55% to £4.6m.





Ingredients: Freshly Prepared Chicken (45%), Mussels (3%), Chicken Broth (47%), Sunflower Oil, Minerals, Tapioca, Tuna Oil.

Price £1.25g for a 70g tin (Mussel content £17.80 per kilo)



Source: The Grocer

# **Mussels for joint care**

The link between green-lipped mussels and joint health is even more established in consumers' minds in the pet food market. Green-lipped mussel extract is often listed in the ingredient declarations of product ranges for senior dogs, cats and horses and is recommended by vets.



Business

#### Ingredients

#### **Green Lipped Mussel**

ActivEase @ Green Lipped Mussel from the crystalclear waters of New Zealand provide an incredibly concentrated source of Omega 3, which is proven to soothe stiff joints. Ours contains 4x more active Omega 3 than standard versions.

#### Vitamins C and E

Neutralise free radicals helping to maintain joint mobility.

#### Glucosamine

Provides the major building blocks of cartilage – the tough connective tissue that protects the joint.

#### Manganese

Supports collagen formation in the cartilage, tendons and ligaments.

#### Hyaluronic Acid

Helps to lubricate and cushion the joint. YuMOVE Dog is the only joint supplement range with Hyaluronic Acid proven to reach the joint within 2 hours. It helps support the synovial fluid, which lubricates your dog's joints

\*Study conducted by Royal Veterinary College. \*\* Kynetec VetTrak January 2021. Sales of YuMOVE branded products through veterinary wholesalers.

#### © New Nutrition Business

Yumove is a joint health supplement brand aimed at, unusually, both animals and humans. It features green lipped mussel extract as its signature joint health supplement

#### What is it?

YuMOVE Dog, now YuMOVE Adult Dog, is our original triple action dog joint formulation, recommended for older dogs that are beginning to show joint stiffness. YuMOVE provides a concentrated source of Omega 3s proven to soothe stiff joints and maintain joint comfort. It is a tasty tablet that you feed daily, available in 60, 120 tablets or 300 tablets. Helping over 1 million pets globally.



#### © New Nutrition Business

#### ZIWI is a New Zealand pet food company dedicated to premium pet foods with a strong provenance and high0guality ingredients focus.

- Green Lipped Mussels are one of its key ingredients, alongside kelp, ٠ tripe or poultry heart. These are part of the Z-Boost Superfoods blend that is used in Ziwi products.
- Ziwi products are available in New Zealand, Australia, South Korea ar ٠ Europe.

Our PeakPrey™ recipes are rich in meat, organs, bone and seafood, with added superfoods for a nutritional boost.

Case Study: Ziwi

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Every ZIWI® Peak recipe is made without unwanted carbohydrates and is free from artificial preservatives.

# Z-BOOST™ SUPERFOODS

The ultimate nutritional boost, every ZIWI® Peak recipe features a minimum of 10% superfoods™ a blend of cold-washed green tripe or poultry heart, whole New Zealand green mussels and organic kelp. Nature's powerhouse source of vitamins, minerals, and antioxidants to support brain, heart, and joint function while contributing to skin and coat health.







# Provenance

Inspired by New Zealand's rich culture and diverse landscape, these wet recipes feature 5 meats and fish from a single region in New Zealand. A delicious topper or complete meal, offering the ultimate nutrition for your cat.

**Ziwi Peak Hauraki Plains for Cats:** a ready to serve raw alternative product with Z-Boost superfood blend of poultry heart, New Zealand green mussels and kelp,

**Ingredients:** chicken, whole kahawai, duck, chicken heart, turkey, chicken necks, chicken liver, whole eggs, **New Zealand green mussel**, chicken bone, lecithin, duck bone, inulin from chicory, dried kelp, dried apple pomace, minerals (dipotassium phosphate, magnesium sulfate, zinc amino acid complex, iron amino acid complex, copper amino acid complex, manganese amino acid complex, sodium selenite), turkey gizzard, turkey liver, turkey bone, preservative (citric acid, mixed tocopherols), salt, DLmethionine, turkey heart, vitamins (choline chloride, thiamine mononitrate, pyridoxine hydrochloride, folic acid, vitamin D3 supplement), taurine





# Joint health treats examples

# Yakult PETKULT Sticks

### South Korea

Business

"Dog snack made with Korean Yakult probiotics, and contains green tea extract for oral health; and MSM, glucosamine, shark cartilage, green lipped mussels and boswellia for joint health."



Ingredients: rice powder, cellulose, glycerin, propylene glycol, chicken hydrolysate, collagen, SHMP, probiotics MPRO3, glucosamine, green tea extract, MSM (methylsulfonylmethane), shark cartilage (chondroitin), green lipped mussel, boswellia, cinnamon, vitamin complex (vitamin A, vitamin B12, vitamin D, vitamin E), mineral complex (calcium, iron, zinc), amino acid complex (DL-methionine, L-lysine), potassium sorbate NewNutrition

# Pablo Dental Chewing Sticks with green lipped mussels Germany

"Supplement for adult dogs enriched with vitamins A, D3 and E, that supports joints due to its green-lipped mussel powder and promotes mobility."



**Ingredients:** cereals, meat and animal by-products, vegetable by-products, mussels and crustaceans (mussel powder (1.1%), crustacean meal (1.1%)), additives (nutritional additives (vitamin A, vitamin D3, vitamin E, copper (copper II sulphate pentahydrate)), technological additives (antioxidant, preservative), sensory additives (colours))

# The price for mussels used as ingredients in pet foods compares well with that for human consumption

Prices for mussels in pet food products can often be higher than in human food products.

The market for premium pet food is growing quickly and this this may offer a viable additional income stream for Scottish mussel producers.



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# 7. NZ mussel industry case study



The New Zealand green-lipped mussel industry has been a pioneer of the marine extracts and nutraceuticals industry since the 1970s and is a global success story.

There are a number of factors which have led to New Zealand's success in nutraceuticals from mussels :



Focus on value add products and export markets as primary drivers of growth.



Early identification of the potential link between green-lipped mussels and joint health benefits



Mussel powder and oils are not seen as route for waste stream from mussel processing. The two markets developed in tandem, and both use the highest quality raw material



A variety of commercial uses have been found for the waste shell from the half shell product – use in concrete in the construction industry, as a soil improver for vineyards, and as an ingredient in chicken feed



Investment in long-term research programme



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Business

Effective collaborative marketing using the industry trademark **Greenshell**<sup>™</sup> and focusing on unique health benefits and production from pristine environment

# NZ mussel industry development – key events timeline

Pre-1960s	Green lipped mussels have been a dietary staple for coastal Maori dwellers. Mussels were gathered from inter-tidal rocks for local consumption. Rocks were often moved and strategically placed to maximise mussel harvest
1960s	Industry began mussel dredging which soon destroyed some of key beds
1969	Various entrepreneurs independently set up experimental commercial scale cultured mussel farms featuring ropes tied to rafts moored in inshore waters
1971	<ul> <li>US scientists screening marine extracts for anticancer properties discovered anti- inflammatory properties of greenshell mussels in a sample sent by Stuart Macfarlane.</li> <li>first cultured green shell mussels went on sale in NZ</li> </ul>
1974	harvesting of spat from seaweed collected on Ninety Mile Beach, still the primary source of spat today
1981	mussel powder sales to the US collapsed overnight when the FDA introduced new stringent legislation on supplements
1982	exporting of greenshell mussels from New Zealand begun
2011	Commercial scale mussel oil production begins

# **Market overview**

As a small country (population 5 million, comparable to Scotland), New Zealand has always been exportfocused for growth. Exports account for the majority of mussel sales.



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Source: Seafood New Zealand, Aquaculture NZ

USA NZ\$97.3m

China NZ\$53.7m

Korea NZ\$32.2m Thailand NZ\$18.8m

# **Supply chain**

The number of aquaculture businesses has declined over the last 15 years in New Zealand, as the industry has consolidated and supply chains have become more fully integrated. Larger companies such as Aroma NZ and Maclab/ Pharmalink have developed are working towards enclosed supply chains encompassing processing and production of extracts and supplements.



#### NZ seafood industry businesses

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NZ mussel sales volume (tonnes) Source: MBIE, Seafood New Zealand, NZGeo

# **Supply chain**

Green-lipped mussel aquaculture provides one of the highest value returns per hectare in NZ cultivation, surpassed only by salmon farming.

Comparison of the approximate annual value per 10 farmed hectares for different primary products		
Salmon	\$140,000,000	
Mussels	\$850,000	
Oysters	\$800,000	
Kiwifruit	\$800,000	
Dairy	\$77,000	
Sheep and beef	\$8,500	

Source: Zespri, Beef+Lamb, DairyNZ, AQNZ

# **Supply chain**

Another notable feature of the NZ supply chain is how integrated the production of mussels and other bivalves is with the wider seafood industry. The largest companies in the NZ industry have a broad portfolio of interests encompassing aquaculture of shellfish and salmon, wild sea fishing, fish and shellfish processing and extraction of nutritional compounds.

In recent years, much of the investment in the mussel industry has come from these large conglomerates.



NZ's largest diversified seafood fishing, aquaculture and marketing company with exports 82% of revenue; NZ's largest quota holder of fishing rights, 23%; largest Green Lipped Mussel producer; 2nd largest King Salmon producer in NZ; 50 vessels, 210 farms, 7 processing sites. T/o 2020 NZ\$ 469m



Vertically integrated seafood company comprising fishing, aquaculture, processing and marketing; operating in NZ and AU; exports 90% of NZ catch to over 40 countries; significant global investments. T/o 2020 \$450m



#### Investment in Plant & Equipment 2015-2017 (NZ\$m)

Source: MBIE

# Investment

There have been several high profile investments in the NZ seafood industry by Asian companies in the last 5 years



Source: MBIE



# **Investment in research**

Underpinning the growth in the mussel industry in New Zealand is a long term public sector investment in scientific research and technological development.

The New Zealand Government has funded industry research for over 20 years, with projects selected in consultation with industry bodies such as Aquaculture New Zealand. They also provide research funding for individual companies and consortia on a 50:50 basis

Some current research priorities and ongoing projects:

- Clinical trials into benefits of green-lipped mussel oil on inflammatory diseases
- Breeding programme for improved characteristics such as increased growth, higher levels of bioactive compounds, increased nutritional value and resilience to pests and climate change
- Improvement in extraction techniques to capture the maximum nutritional value from the raw material
- Production of spat on land based farms, to reduce reliance on gathering from washed up seaweed
- Research into open ocean production techniques and scale up
- Al applications for waste reduction and improvement in product quality

# **Mussel oil**

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The development of mussel oil has been critical to the growth and security of the NZ mussel industry over the last 10 years.

Mussel powder has become something of a commodity product with large producers such as Chile also entering the market. Mussel oil however is currently only produced in NZ where the technology was developed, and is the highest quality mussel extract available.

During the COVID-19 pandemic, the global price of mussel powder has fluctuated significantly, but the price of the higher quality mussel oil product remained stable. Mussel oil now accounts for 12% of the mussel export market for New Zealand.

> The market value of bulk greenlipped mussel oil is NZ\$ 3000 per kg







Source: Seafood New Zealand, Aquaculture NZ,

# Mussel oil Case study: PernaTec



PernaTech<sup>™</sup> is a joint health supplement brand owned and manufactured by PharmaZen. The product uses high quality green-lipped mussels from accredited farms which are freeze dried into powder and then further processed to extract the oils.



ory	Raw Material:	New Zealand Greenshell mussels (perna canaliculus), sustainably grown in an aquaculture environment
acids.	Colour:	Dark amber coloured liquid
	Packaging:	MAP ( modified air)
arine	Total Fat:	>99%
	Triglycerides and Free Fatty Acids:	50% -60%
	Omega 3 Fatty Acids:	20% -40%
	Phospholipids:	40% -50%
	Sterols:	1%-2%

#### PernaTec<sup>™</sup> Advantages

- Highly effective anti-inflammatory ingredient
- Rich in essential Omega 3 fatty acids, EPA & DHA
- Additional health benefits of marine phospholipids and sterols
- Sustainably farmed
- Non GMO

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- 100% natural
- Fully traceable