02

# A GUT-CENTRED, MULTI-SEAWEED FRAMEWORK FOR MODERN CANINE NUTRITION

How fermentative green seaweeds, supported by complementary marine bioactives, can improve gut robustness, tolerance and whole-dog wellbeing

OCEAN HARVEST TECHNOLOGY

# EXECUTIVE SUMMARY

Gut health is increasingly recognised as a central determinant of wellbeing in dogs, influencing stool quality, digestive tolerance, immune balance, skin and coat condition, behaviour, and overall vitality. Many of the outcomes most visible to pet owners are now understood to be downstream expressions of gut ecology rather than isolated nutritional effects.

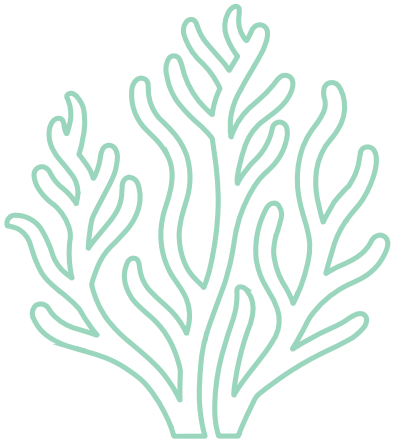
Within this context, marine macroalgae have emerged as valuable functional ingredients in canine nutrition, particularly through their unique polysaccharides, fibres, and bioactives that resist upper gastrointestinal digestion and interact directly with the gut microbiome.

**Green seaweeds** play a central role in this framework. Their rhamnose-rich sulphated polysaccharides and highly fermentable fibre fractions act as effective substrates for microbial fermentation, supporting short-chain fatty acid production, stool consistency, and digestive comfort. As a result, green seaweeds can reasonably be considered a foundational gut-active marine ingredient in modern canine diets.

**Brown and red seaweeds** contribute complementary functionality. Brown seaweeds provide fucoidans and polyphenols that support immune modulation, epithelial integrity, and keratinised tissues, while red seaweeds contribute sulphated galactans and gel-forming fibres that help stabilise gut hydration, barrier function, and digestive comfort. When combined with green seaweeds, these groups extend functional coverage and improve robustness across individuals, life stages, and diet types.

This white paper presents a **gut-centred,** multi-seaweed framework for canine nutrition that builds from a green-seaweed-driven fermentative foundation and integrates complementary marine bioactives to support balanced gut ecology. Rather than positioning seaweed as a single-purpose additive, this approach treats marine ingredients as a system-level nutritional platform capable of supporting multiple physiological and functional domains simultaneously.

The framework is grounded in independent canine nutrition research, established marine polysaccharide science, and exploratory microbiome observations in dogs. All observational data are presented as hypothesis-generating and directional in nature, intended to inform further validation rather than replace controlled in-home feeding trials.



We build from the established value of green seaweeds as fermentative, gut-active ingredients, and exploring how complementary brown and red seaweeds can be used to complete and stabilise this foundation.

- Explaining the complementary roles of brown, green, and red seaweeds
- Recognising the established value of Ascophyllum
- Addressing common misconceptions that often limit seaweed use to dental health
- Predicting canine outcomes based on known science
- Aligning these predictions with observed effects in dogs and other species
- Positioning multi-seaweed blends as **multi-purpose ingredients**, not single-claim additives

**The central thesis is simple:**

**In dogs, many of the most valued outcomes — stool quality, coat condition, behaviour, immune resilience, and vitality — are downstream expressions of gut health. Multi-seaweed nutrition acts upstream, at the level of gut ecology.**

OceanFeed™ Pet is formulated as a green-seaweed-first system, in which fermentative and microbiome-active polysaccharides are supported by complementary brown and red seaweeds to broaden functional coverage and improve robustness.

> We present a systems-based framework supported by established science and early exploratory observations, intended to inform further validation rather than replace controlled in-home trials. All observational and microbiome data presented are exploratory in nature.

# THE MARINE BIOACTIVE LANDSCAPE: BROWN, GREEN, AND RED SEAWEEDS

The three major macroalgal groups differ radically in composition. *(O'Sullivan et al., 2010; Xie et al., 2023)*

## BROWN SEAWEEDS

Brown macroalgae are characterised by a distinctive suite of sulphated and non-sulphated polysaccharides and polyphenolic compounds, most notably fucoidans, laminarins, alginates, and phlorotannins, alongside a naturally high mineral and trace element content. *(O'Sullivan et al., 2010; Xie et al., 2023)*

**Key bioactives:**

- Fucoidans (sulphated fucose-rich polysaccharides)
- Laminarin (β-glucan storage polysaccharide)
- Alginates (gel-forming structural polysaccharides)
- Phlorotannins (marine polyphenols)
- Marine-derived minerals

**Known biological actions:**

- Independent studies demonstrate that brown seaweed polysaccharides and polyphenols:
- Modulate innate immune signalling, including reductions in pro-inflammatory cytokine activity and altered immune cell responses *(Ale et al., 2011; Fitton et al., 2015)*
- Support epithelial and barrier integrity, through effects on cell differentiation and structural maintenance *(Yao et al., 2023)*
- Exert antimicrobial and anti-adhesive effects against selected microbial species, contributing to microbial balance rather than broad-spectrum suppression *(Fitton et al., 2015)*
- Influence keratinocyte differentiation and tissue structure, supporting skin and keratinised tissue integrity at a cellular level *(Chen et al., 2019; Song et al., 2014)*
- Provide antioxidant activity, largely via phlorotannins and associated polyphenols, contributing to reduced oxidative load *(Ale et al., 2011; Xie et al., 2023)*

**Relevance to dogs:** In dogs, brown seaweeds are primarily relevant for their **effects on immune tone, epithelial and barrier integrity, and keratinised tissues,** rather than as major fermentative substrates. Fucoidans and polyphenols modulate innate immune signalling and support inflammatory balance (Ale et al., 2011; Fitton et al., 2015) while fucoidan-specific studies support keratinocyte differentiation and epidermal barrier biology (Chen et al., 2019; Song et al., 2014), This is particularly relevant given the recognised links between immune signalling, barrier integrity and inflammatory skin conditions in dogs (Marsella, 2011).

***These effects complement, rather than replace, the fermentative and microbiome-driven activity provided by green seaweeds.***

## GREEN SEAWEEDS

Green macroalgae are distinguished by their content of rhamnose-rich sulphated polysaccharides (ulvans), alongside chlorophyll derivatives and highly fermentable soluble fibre fractions. (O'Sullivan et al., 2010; Xie et al., 2023)

**Key bioactives:**

- Ulvans (rhamnose-rich sulphated polysaccharides)
- Fermentable soluble fibres
- Chlorophyll-associated compounds

**Known biological actions:**

Studies consistently show that green seaweed polysaccharides:

- Resist digestion in the upper gastrointestinal tract, allowing delivery to the hindgut for microbial fermentation (O'Sullivan et al., 2010; Charoensiddhi et al., 2022)
- Are selectively fermented by gut microbiota, stimulating fibrolytic and butyrate-producing bacterial taxa, including members of the Ruminococcaceae and Lachnospiraceae families (Seong et al., 2019; Han et al., 2019)
- Increase total short-chain fatty acid production, including butyrate, a key energy source for intestinal epithelial cells (Cherry et al., 2019; Charoensiddhi et al., 2022)
- Modulate inflammatory signalling, including suppression of LPS-driven immune activation (Leiro et al., 2007)
- Contribute antioxidant activity, through associated pigments and polysaccharide-linked effects (Xie et al 2023, Tanna & Mishra, 2018)

**Relevance to dogs:** Dogs respond rapidly to changes in fermentable substrate supply, and canine feeding studies show that fermentable fibres shift microbiome composition and fermentation outputs with downstream impacts on stool quality and digestive tolerance (Middelbos et al., 2007; Beloshapka et al., 2013; Swanson et al., 2002). Given that seaweed polysaccharides resist upper-GI digestion and are selectively fermented to increase SCFAs including butyrate (Charoensiddhi et al., 2022; Cherry et al., 2019), green seaweeds are therefore particularly relevant as prebiotic substrates supporting microbial balance and stable fermentation in dogs.

***For many canine formulations, green seaweeds can reasonably be considered the core functional driver within marine ingredient strategies, providing the primary fermentative substrate upon which broader gut and systemic effects are built.***

## RED SEAWEEDS

Red macroalgae contain structurally distinct sulphated galactans, including agarans, carrageenans, and porphyran, alongside unique polyphenolic compounds.

**Key bioactives:**

- Sulphated galactans (agarans, carrageenans, porphyran)
- Gel-forming soluble fibres
- Red seaweed polyphenols

**Known biological actions:**

Evidence indicates that red seaweed polysaccharides:

- Form hydration-stable gels within the gastrointestinal tract, influencing digesta viscosity and water retention (Xie et al, 2023; O'Sullivan et al., 2010)
- Support short-chain fatty acid production, through microbial fermentation of sulphated galactans (Zhu et al., 2021; Cherry et al., 2019)
- Exert antioxidant effects, contributing to redox balance (Zhang et al., 2015; Xie et al., 2023)
- Modulate inflammatory pathways, supporting controlled immune signalling and mucosal comfort (Ale et al., 2011; Zhang et al., 2015)
- Contribute to intestinal barrier support, through combined physical and biochemical mechanisms (Yao et al., 2023, Zhu et al., 2021)

**Relevance to dogs:** In dogs, red seaweeds are most relevant through their water-binding/hydrocolloid behaviour and antioxidant/anti-inflammatory potential, which can support digestive comfort and stool consistency, alongside broader barrier-supporting mechanisms (Xie et al., 2023; Yao et al., 2023; Zhang et al., 2015). Canine feeding studies demonstrate that fermentable substrate characteristics and microbiome responses are closely linked to stool quality and gut tolerance (Middelbos et al., 2007; Beloshapka et al., 2013), supporting the rationale for including red seaweed galactans as part of a broader fermentation- and barrier-centred nutritional strategy (Zhu et al., 2021; Cherry et al., 2019).

***In a blended context, these properties help stabilise the physical gut environment in which green-seaweed-derived fermentation occurs.***

# CHALLENGING MISCONCEPTIONS ROOTED IN HISTORICAL PATTERNS OF SEAWEED USE

This section addresses a species-specific context unique to dogs, where seaweed use is already established but narrowly defined, and explains why this history both enables and constrains broader nutritional applications.

## THE DOMINANCE OF *ASCOPHYLLUM* IN PET APPLICATIONS

***Ascophyllum nodosum* is widely used in dog food and supplements, primarily for:**

- Oral and dental health
- Reduction of plaque-forming bacteria
- Natural mineral contribution

Independent studies demonstrate that Ascophyllum polyphenols and fucoidans reduce oral bacterial adhesion and plaque formation in dogs, supporting its established role in dental chews and supplements (Gawor et al., 2018).

This value is not disputed.

**However, in most pet foods, seaweed inclusion has remained functionally narrow, despite growing recognition that:**

- Gut health strongly influences skin, coat, stool quality, immunity, and behaviour (Marsella, 2011; Middelbos et al., 2007; Beloshapka et al., 2013)
- Pet owners increasingly expect multiple benefits from a single ingredient
- Formulators seek ingredients that deliver both nutritional and processing advantages

## THE MISCONCEPTION: "SEAWEED = ASCOPHYLLUM"

Because *Ascophyllum* has dominated historical use, seaweed is often viewed primarily as:

- A dental additive
- A mineral source
- A flavour or "superfood" inclusion

**This overlooks the fact that marine macroalgae represent a structurally and functionally diverse group:**

- Green seaweeds contain highly fermentable rhamnose-rich sulphated polysaccharides
- Red seaweeds provide gel-forming galactans with distinct water-binding and antioxidant properties
- These compounds are not present in meaningful amounts in brown seaweeds alone (O'Sullivan et al., 2010; Xie et al., 2023)

In short, Ascophyllum is valuable and well validated, but functionally specialised.

## MANAGING IODINE AND HEAVY METALS IN SEAWEED-BASED PET NUTRITION:

Why blends enable both safety and functionality**

Heavy metals and iodine content are among the primary reasons pet food manufacturers either avoid seaweed entirely or restrict its use to very low inclusion rates. **These concerns are justified:**

- Seaweeds are mineral-rich by nature
- Certain species, particularly brown kelps and Ascophyllum, can accumulate iodine and trace elements
- Regulatory scrutiny in pet food is stringent
- Manufacturers require predictability, compliance, and margin of safety

Natural iodine variability across seaweed species is well documented (Teas et al., 2004).

As a result, seaweed is often used only as a minor label inclusion or restricted to specific applications (e.g. dental health via Ascophyllum).

However, this risk-focused approach has had an unintended consequence: it has prevented manufacturers from accessing the broader nutritional and functional benefits that seaweed can provide.

## WHY SINGLE-SPECIES STRATEGIES CAN LIMIT FUNCTIONAL SCOPE

**Brown seaweeds such as *Ascophyllum* and *Laminaria* are:**

- Highly effective sources of fucoidan and polyphenols
- Valuable for oral health, immune modulation, and tissue support
- Intrinsically higher in iodine than most other seaweed groups (Teas et al., 2004)

When used alone, this creates a practical ceiling on inclusion, driven by iodine exposure rather than nutritional logic.

The limitation is not seaweed — it is reliance on a single seaweed type.

## WHY MORE SEAWEEDS CAN BE BETTER THAN ONE

Blending is not intended to correct deficiencies in green seaweed use, but to allow green-seaweed-driven functionality to be expressed at practical inclusion levels while managing mineral exposure and broadening functional coverage.

**Green and red seaweeds differ fundamentally from brown kelps:**

- They contribute fermentable polysaccharides, water-binding fibres, and antioxidants
- They are naturally lower in iodine
- They deliver functionality without proportionally increasing iodine intake (O'Sullivan et al., 2010; Xie et al., 2023)

By combining brown, green, and red seaweeds in defined ratios, it becomes possible to retain the benefits of brown seaweeds while expanding functional scope and increasing safe inclusion.

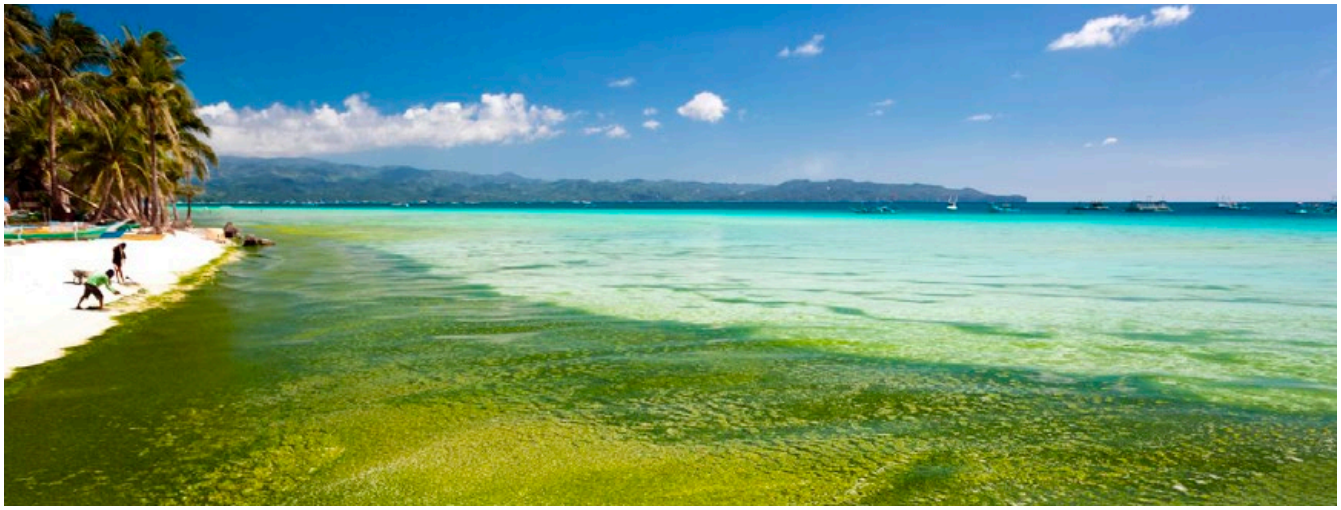
## WHY BEING ABLE TO USE MORE MATTERS

Using more seaweed is not about marketing — it is about unlocking functionality.

**At higher, still-safe inclusion rates, multi-seaweed blends can deliver:**

- Meaningful prebiotic fibre intake
- Measurable effects on stool quality and microbiome balance (Middelbos et al., 2007; Beloshapka et al., 2013)
- Water-binding and texture effects in wet and semi-moist foods
- Reduced reliance on isolated fibres or synthetic binders

These effects cannot occur at token inclusion levels dictated by brown-only iodine limits.



## HEAVY METALS: CONTROL THROUGH SOURCING, BLENDING, AND SPECIFICATION

Seaweeds naturally contain trace elements — this is true of all mineral-rich ingredients.

What matters is control, not avoidance.

**A blended approach offers three practical advantages:**

**1. Source diversification**
Reduces dependence on any single harvest location or species

**2. Smooths biological variability**
More consistent year-round functional outcomes

**3. Matrix dilution**
Prevents concentration of any one trace element

**4. Specification-led formulation**
Allows manufacturers to work from known, audited ranges rather than worst-case assumptions

The OceanFeed™ Seaweed Blend is explicitly positioned as a specification-driven ingredient, not a variable raw material — a critical distinction for pet food manufacturers operating at scale.

## REFRAMING THE CONVERSATION FOR PET FOOD MANUFACTURERS

The traditional view has been:

> *"Seaweed is risky, so we use very little — or avoid it."*

A multi-seaweed, specification-led approach enables a different conclusion:

**By using more than one seaweed, we reduce risk, increase safe inclusion, and unlock significantly more nutritional and functional value.**

## PREDICTED CANINE EFFECTS BASED ON INDEPENDENT SCIENCE

The predicted effects outlined below are derived from established canine feeding studies and cross-species research on marine polysaccharides, fermentation, immune signalling, and barrier integrity. They are presented as biologically plausible outcomes arising from known mechanisms, not as confirmed clinical effects of OceanFeed™.

## PREDICTED EFFECTS ON GUT MICROBIOME, FERMENTATION, AND STOOL QUALITY

Marine polysaccharides derived from **brown, green, and red seaweeds** share a key functional property: resistance to digestion in the upper gastrointestinal tract, allowing them to reach the colon intact and act as substrates for microbial fermentation (O'Sullivan et al., 2010; Charoensiddhi et al., 2022).

Canine feeding studies demonstrate that fermentable fibre structure strongly influences microbiome composition, short-chain fatty acid (SCFA) production, and stool quality, with butyrate playing a central role in epithelial energy supply and mucosal integrity (Middelbos et al., 2007; Beloshapka et al., 2013). Cross-species studies show that seaweed-derived polysaccharides are selectively fermented, stimulating fibrolytic and butyrate-producing taxa and increasing total SCFA output (Cherry et al., 2019; Han et al., 2019; Seong et al., 2019).

**In dogs, these mechanisms predict:**

- More stable fermentation profiles, supporting consistent stool firmness and reduced flatulence
- Improved tolerance to dietary change, particularly during transitions in protein source, life stage, or formulation
- Reduced susceptibility to fermentation imbalance, a common contributor to gastrointestinal upset in dogs

These effects are especially relevant given the sensitivity of the canine gut to dietary perturbation and the close relationship between fermentation balance and stool quality.

## SKIN, COAT, AND BARRIER FUNCTION

Canine dermatology research highlights strong links between gut inflammation, oxidative stress, immune signalling, and skin barrier function, particularly in conditions characterised by chronic or low-grade inflammation (Marsella, 2011). Dietary modulation of gut ecology and immune tone is therefore increasingly recognised as an upstream influence on skin and coat health, particularly in inflammation-prone or sensitive dogs.

> Marine bioactives, including fucoidans and polyphenols from brown and red seaweeds, have been shown to reduce inflammatory signalling, support keratinocyte differentiation, and enhance epithelial barrier integrity in independent studies (Ale et al., 2011; Chen et al., 2019; Song et al., 2014; Yao et al., 2023). Antioxidant activity further contributes to reduced oxidative load, which is known to impair barrier function and tissue resilience (Zhang et al., 2015).

**In dogs, these mechanisms are consistent with:**

- Improved skin comfort and barrier resilience, particularly in inflammation-prone individuals
- Enhanced coat condition and reduced shedding, as downstream expressions of improved systemic and epithelial health

These effects arise indirectly through modulation of gut–immune–skin pathways rather than through direct topical or pharmacological action.

## BEHAVIOUR, GUT COMFORT, AND THE MICROBIOTA–GUT–BRAIN AXIS

Short-chain fatty acids produced during colonic fermentation, particularly butyrate, act not only as energy substrates but also as signalling molecules within the microbiota–gut–brain axis, influencing serotonin metabolism, vagal signalling, and neuroinflammatory tone (Cryan & Dinan, 2012; Dalile et al., 2019).

> While direct behavioural intervention studies in dogs are limited, canine and cross-species research supports a link between gut comfort, fermentation balance, inflammatory signalling, and behavioural expression, particularly in stress-sensitive or anxious individuals (Zentek et al., 2003; Bested et al., 2013).

**By supporting stable fermentation and reducing gut-derived inflammatory and discomfort signals, marine polysaccharide-driven modulation is consistent with emerging gut–brain axis research and is expected to support behavioural comfort in sensitive dogs:**

- Calmer demeanour and improved behavioural stability
- Reduced stress-related reactivity associated with gastrointestinal discomfort

These effects should be understood as indirect outcomes of improved gut comfort and metabolic signalling, not as direct neurological effects.

## IMMUNE RESILIENCE AND SYSTEMIC BALANCE

Marine polysaccharides have been shown to modulate innate immune responses, reducing excessive inflammatory activation while maintaining appropriate immune vigilance (Ale et al., 2011; Leiro et al., 2007). Improved barrier integrity further reduces immune stimulation driven by luminal antigens and microbial translocation (Yao et al., 2023).

**In dogs, where immune dysregulation is often linked to gastrointestinal and dermatological conditions, these mechanisms predict:**

- More balanced immune tone, with reduced background inflammation
- Greater resilience to environmental, dietary, and physiological stressors

Importantly, these effects reflect nutritional modulation of immune ecology, not immune stimulation or suppression.

## WHY A MULTI-SEAWEED APPROACH CAN BE BIOLOGICALLY ADVANTAGEOUS IN DOGS

The table below should be read as a map of functional coverage rather than a performance ranking. Green seaweeds form the core fermentative driver in this framework, while brown and red seaweeds extend functionality into immune modulation, barrier support, and physical gut stability.

| Functional Area | Brown seaweeds (Ascophyllum-type) | Green-type marine polysaccharides | Red-type marine polysaccharides | Multi-seaweed blend |
|---|---|---|---|---|
| Dental / oral health | ✓✓ | — | — | ✓✓ |
| Gut microbiome support | — | ✓✓ | ✓ | ✓✓✓ |
| Prebiotic fermentation & SCFA production | — | ✓✓ | ✓ | ✓✓ |
| Stool quality & firmness | — | ✓ | ✓✓ | ✓✓✓ |
| Gut barrier & digestive comfort | ✓ | ✓ | ✓✓ | ✓✓✓ |
| Skin & coat health | ✓ | — | ✓ | ✓✓ |
| Immune resilience | ✓ | ✓ | ✓ | ✓✓ |
| Behavioural calm & wellbeing | — | ✓ | ✓ | ✓✓ |
| Product moisture & texture (processing) | — | — | ✓✓✓ | ✓✓✓ |
| Dose flexibility & mineral management | — | ✓✓✓ | ✓✓✓ | ✓✓✓ |

Legend:
✓ = supporting or plausible contribution
✓✓ = established or well-supported contribution
✓✓✓ = primary or system-level contribution
— = not a reliable or consistent function at practical inclusion levels

Interpretation: In dogs, many owner-visible outcomes such as stool quality, coat condition, and calm behaviour are downstream expressions of gut health. Multi-seaweed blends enable safe inclusion rates that unlock prebiotic, stool-stabilising, and processing benefits beyond what brown seaweed alone can deliver, while managing iodine exposure through species selection and blending (Teas et al., 2004)

** Behavioural effects reflect indirect modulation via fermentation-derived metabolites, gut comfort and inflammatory signalling, not direct neurological action.*

Note: Functional attributions reflect group-level properties of marine macroalgae and known polysaccharide biology. Tables do not imply disclosure of specific species composition, nor discrete clinical claims.

# PATENTS, MECHANISM COHERENCE, AND THE CENTRAL ROLE OF GUT HEALTH IN CANINE NUTRITION

## HOW OCEANFEED'S PATENTED CONCEPTS REINFORCE THE SCIENCE

Two granted patents underpin the development and application of OceanFeed™. While differing in scope, both are built around a common mechanistic principle: that combinations of marine macroalgae can be used to beneficially influence gastrointestinal function and microbiota, and that improvements in gut health subsequently manifest as broader health and resilience outcomes across species and life stages.

> Rather than claiming isolated or ingredient-specific "effects," the patents codify a systems-based nutritional approach, where gut health is treated as the primary lever through which multiple downstream benefits are expressed. Improvements in wellbeing, tolerance, or resilience are described as downstream consequences of microbiome modulation and improved gut function, rather than as direct effects of the seaweed blend itself.

This framing aligns closely with contemporary companion-animal nutrition, where gut ecology is increasingly recognised as a central determinant of digestive comfort, immune balance, and behavioural stability.

## FROM FORMULATION CONCEPT TO BIOLOGICAL MECHANISM

**At a high level, the patents describe the use of multi-seaweed blends (brown, green, and red macroalgae) at practical inclusion rates to:**

- Modulate the gastrointestinal microbial ecosystem
- Support digestive efficiency and epithelial barrier integrity
- Reduce unnecessary inflammatory and oxidative load
- Enhance utilisation of nutrients already present in the diet

This approach reflects modern nutritional science, which recognises the gut not as a passive digestive tube, but as a dynamic interface between diet, immunity, metabolism, and behaviour.

Importantly, the patents do not rely on any single seaweed species or any single bioactive compound. Instead, they formalise the understanding that different seaweed groups contribute distinct but complementary polysaccharides and bioactives, and that the combination is what enables reliable, repeatable functional outcomes.

## ALIGNMENT WITH INDEPENDENT SCIENCE

**Independent literature supports this division of functional roles:**

- Brown seaweeds provide fucoidans, laminarins, alginates, and polyphenols that support immune modulation, epithelial integrity, antimicrobial balance, and keratinocyte function.
- Green seaweeds supply highly fermentable rhamnose-rich polysaccharides that selectively stimulate fibrolytic and butyrate-producing bacteria, supporting colonic fermentation and microbial balance.
- Red seaweeds contribute sulphated galactans and gel-forming fibres that stabilise gut hydration, support mucosal comfort, and provide antioxidant and anti-inflammatory activity.

The patents reflect this same "division of labour" at a conceptual level: microbial ecology, immune tone, physical gut environment, and nutrient utilisation are addressed simultaneously rather than sequentially.

> This distinguishes the patented approach from many conventional pet food additives, which are typically designed to act on a single target (e.g. mineral supplementation, fibre addition, microbial suppression, or binding activity).

Recent reviews further demonstrate that interactions between seaweed polysaccharides and polyphenols enhance colonic bioactivity, SCFA production, and microbiome modulation, providing a mechanistic basis for multi-component marine formulations rather than isolated compounds (Lee et al., 2025).

## WHY GUT HEALTH SITS UPSTREAM OF MANY OWNER-VISIBLE OUTCOMES IN DOGS

Across species, improvements in gut ecology are associated with a range of downstream outcomes that vary according to physiology and context. **In dogs, these commonly include:**

- Improved stool consistency and digestive tolerance
- Enhanced skin and coat condition
- Greater behavioural stability and comfort
- Improved resilience during dietary or environmental stress

**The underlying logic lies in the central role of the gut:**

**1.** Improved microbial balance increases production of beneficial metabolites such as short-chain fatty acids (e.g. butyrate).

**2.** Improved barrier integrity reduces immune activation driven by gut-derived antigens.

**3.** Lower background inflammation reduces diversion of energy and nutrients away from maintenance and repair.

**4.** More efficient nutrient utilisation improves overall dietary efficiency without increasing intake.

**5.** Gut–brain signalling influences comfort, stress reactivity, and behavioural expression.

From this perspective, changes in stool quality, coat condition, or behaviour are not separate effects, but downstream expressions of a healthier and more stable gut environment.

The patents formalise this logic

> Intervene at the level of gut ecology and allow the animal's own physiology to express the benefits.

## RELEVANCE TO DOGS: TRANSLATING THE SAME MECHANISM INTO CANINE OUTCOMES

**Dogs are particularly sensitive to changes in gut health because:**

- They respond rapidly to changes in fermentable substrate supply
- Fermentation imbalance readily manifests as stool inconsistency, gas, or discomfort
- Low-grade gut inflammation is linked to dermatological and behavioural issues
- Digestive discomfort often precedes visible health changes

Within this context, the patented multi-seaweed concept helps explain why modest shifts in gut ecology can produce disproportionately visible benefits in dogs, particularly when dietary transitions, sensitivities, or life-stage changes are involved.

These outcomes reflect improved tolerance and resilience, not pharmacological or performance-enhancing effects.

## A MULTI-PURPOSE NUTRITIONAL PLATFORM, NOT A SINGLE-PURPOSE ADDITIVE

The patents frame OceanFeed™ not as a narrowly defined additive, but as a multi-purpose nutritional platform.

**Many commonly used pet nutrition products are effective but limited in scope:**

- A fibre improves stool
- A calming supplement targets behaviour
- A coat supplement targets appearance
- A mineral source supplies trace elements

**OceanFeed™**, by contrast, acts upstream on gut ecology and function, allowing multiple systems to benefit simultaneously.

This does not replace targeted interventions where those are clearly indicated. Rather, it provides a foundational nutritional layer that can reduce reliance on multiple single-purpose products and improve overall dietary robustness.

## SUMMARY

The patents reinforce a central and increasingly well-supported concept in canine nutrition:

> Improving gut health is one of the most powerful ways to improve whole-dog wellbeing, tolerance, and resilience.

By formalising the use of complementary brown, green, and red seaweeds to influence gut microbiota, immune tone, and digestive efficiency, **the patents provide an intellectual and mechanistic foundation that aligns closely with:**

- Independent scientific literature
- Established biological principles in dogs
- Practical formulation and feeding considerations in companion animals

# ALIGNMENT WITH OBSERVED OUTCOMES IN DOGS

OceanFeed™ is already used at scale by selected pet food manufacturers, and we have also received feedback from consumers using the blend as a supplement. Based on established canine biology, independent scientific literature, and cross-species evidence, it is biologically plausible that the types of effects outlined in Section 3 could be observed in real-world feeding contexts.

> Evaluating diet–microbiome interactions in dogs presents inherent challenges due to individual variability, living environments, and ethical constraints, particularly when compared with controlled production-animal studies. To explore **directional biological responses under controlled dietary conditions,** we undertook a small, exploratory microbiome study within two dog shelters in Ireland.

## PILOT MICROBIOME OBSERVATIONS IN DOGS: DIRECTIONAL EVIDENCE

While anecdotal feedback from individual pet owners has been broadly positive, we recognise the limitations of such observations, including potential expectation bias and lack of dietary control.

To obtain more structured, hypothesis-generating data, we conducted exploratory microbiome analysis on dogs consuming:

- A standard diet alone
- A standard diet supplemented with Ascophyllum alone
- A standard diet supplemented with green seaweed alone
- A standard diet supplemented with a multi-seaweed blend containing brown, green, and red seaweeds

Sampling was performed before and after dietary exposure. Animal numbers were limited, and dogs were housed in a shelter environment rather than private homes. Accordingly, the data are not intended to demonstrate clinical efficacy or population-level outcomes, but to explore whether observed microbiome patterns were directionally consistent with known biological mechanisms.

## RATIONALE FOR A SHELTER-BASED EXPLORATORY MODEL

The canine population relevant to pet food manufacturers is inherently heterogeneous. Dogs may be diet-sensitive, stress-prone, or exhibit unstable digestive function even under good care.

**Shelter environments therefore offer a stress-tested model, in which:**

- Feeding times and diets are more controlled
- Treat and snack intake is minimised
- Staff observations are less influenced by owner expectation
- Baseline gut variability and stress levels are typically higher

While shelter-based studies do not replicate the home feeding environment, they provide a conservative setting for early-stage mechanistic exploration. Observing coherent microbiome patterns under these conditions suggests that responses are diet-driven rather than contextual, supporting the biological robustness of the underlying mechanisms.

## MICROBIOME PATTERNS CONSISTENT WITH PREDICTED MECHANISMS

Within this pilot dataset, single-seaweed inclusions were associated with **directional shifts in the relative abundance of key fermentative taxa,** particularly in dogs with high baseline dominance of individual microbial groups.

> While green-seaweed inclusion was associated with clear fermentative and microbiome shifts consistent with its known biology, the addition of brown and red seaweeds was associated with **broader redistributive patterns.** Microbiome profiles showed convergence toward a more balanced community structure across individuals. This pattern is consistent with **ecosystem-level modulation**, rather than selective amplification of individual bacterial taxa. These patterns suggest a stabilising and balancing effect layered onto a green-seaweed-driven fermentative foundation, rather than a fundamentally different mode of action.

These observations align with the predicted mechanisms described in Section 3 and support a **gut-centred interpretation** rather than isolated or claim-specific effects. Because the observed patterns relate to foundational gut ecology rather than narrow endpoints, they suggest a nutritional approach that may be maintained across life stages and diet types with only modest inclusion adjustments.

## QUALITATIVE OBSERVATIONS FROM SHELTER STAFF

Shelter staff provided qualitative, non-clinical observations for dogs receiving seaweed-supplemented diets, **including reports of:**

- Improved stool firmness
- More stable appetite
- Improved coat appearance over time
- Calmer demeanour and improved approachability

These observations are **not presented as measured outcomes,** nor are they attributed to specific mechanisms. Rather, they are consistent with the types of downstream expressions expected from improved gut comfort, fermentation balance, and reduced background inflammatory signalling.

> Taken together, these pilot observations do not suggest a "single-effect" or intervention-style outcome. Instead, they provide **directional, biologically plausible** evidence supporting further validation through larger, controlled, in-home feeding trials.

We are actively seeking pet food partners for co-development and larger-scale studies to evaluate these mechanisms under real-world feeding conditions.

# **BEYOND NUTRITION:** PROCESSING AND PRODUCT FUNCTIONALITY

**For pet food manufacturers, multi-seaweed blends offer technological and formulation advantages in addition to their nutritional relevance. These benefits arise from the physicochemical properties of marine polysaccharides, particularly their water-binding, gel-forming, and matrix-stabilising behaviour.**

## MOISTURE RETENTION AND TEXTURE

Green and red seaweed polysaccharides exhibit strong hydration and water-binding capacity, which can help to:

- Improve moisture retention in wet and semi-moist foods
- Enhance kibble integrity
- Reduce crumbling and dust
- Improve mouthfeel and palatability

These properties may help mitigate batch-to-batch variability related to moisture loss or ingredient fluctuation and support more consistent consumer acceptance across product lines.

## CLEAN-LABEL FORMULATION

Marine macroalgae can contribute functional fibre, binding, and textural effects while also providing nutritional value. As a result, multi-seaweed blends may allow partial replacement or reduction of:

- Synthetic binders
- Isolated fibre additives
- Artificial texturants

This supports formulation strategies that prioritise clean-label positioning, ingredient multifunctionality, and reduced additive complexity.

> From a sustainability perspective, seaweeds offer a rare combination of functional nutrition and low environmental impact. Multi-species sourcing further reduces pressure on any single ecosystem and can support resilient, diversified supply chains.

## CONSUMER EXPERIENCE, COMPLAINTS, AND RETURNS

Improved stool consistency, digestive tolerance, and smoother dietary transitions are commonly cited drivers of consumer satisfaction in premium pet food categories. By supporting gut comfort and fermentation stability, gut-centred nutritional strategies may contribute indirectly to:

- Reduced incidence of diet-related complaints
- Improved acceptance during product transitions
- Lower rates of product returns

These effects are understood as downstream expressions of improved digestive tolerance rather than direct or guaranteed outcomes.

# **A MULTI-PURPOSE INGREDIENT,** NOT A SINGLE-PURPOSE ADDITIVE

**Many pet food additives are designed to address a single function:**

- Dental support
- Digestive aids
- Skin and coat supplements
- Stool modifiers
- Behavioural or calming products

A gut-centred, multi-seaweed approach allows a single ingredient system to support multiple physiological and functional domains simultaneously. By acting upstream on gut ecology and digestive function, multi-seaweed formulations can support stool consistency, digestive comfort, moisture management, and oral health within a unified framework.

This may assist with a desire to reduce "additive stacking", simplify formulations, and improve label clarity, while maintaining functional performance across multiple product attributes.

**OceanFeed™ can therefore be positioned as a foundational gut-health and functionality platform.**

## CONCLUSIONS FOR CANINE NUTRITION AND PET FOOD DESIGN

- Ascophyllum nodosum remains a valuable and well-established tool for oral health in dogs.
- Building canine nutrition strategies around a single seaweed type can limit access to the broader functional potential of marine macroalgae as dietary complexity and performance expectations increase.
- A multi-seaweed approach aligns with modern understanding of gut-driven health and resilience in dogs.
- Benefits extend beyond nutrition to include processing performance, texture management, and product consistency.
- A blended approach offers broader functional value for manufacturers and pet owners alike.

> In dogs, as in many species, gut health sits upstream of skin, coat, stool quality, immunity, behaviour, and overall vitality. Multi-seaweed nutrition acts at this upstream level, allowing multiple benefits to emerge naturally from improved gut ecology.
>
> Many of the outcomes most visible to pet owners—such as stool quality, coat condition, breath, calmness, and general wellbeing—are closely linked to digestive comfort and microbial balance. By acting on these upstream drivers, multi-seaweed nutrition aligns biological impact with consumer perception.

Green seaweeds remain central to this framework, providing the primary fermentative and microbiome-active foundation. Multi-seaweed blends simply extend this foundation, improving robustness, flexibility, and system-level balance rather than replacing existing approaches.

**This framework provides a rational basis for co-development with pet food manufacturers seeking resilient, multi-functional ingredients, supported by independent science and validated through real-world feeding trials.**

Green seaweeds provide the fermentative engine of gut-active marine nutrition. Brown and red seaweeds contribute complementary immune, barrier, and physical gut-support functions that help stabilise and extend green-seaweed-driven effects across diets, life stages, and product formats.

## APPENDIX – INDEPENDENT SCIENTIFIC REFERENCES

A. DOG-SPECIFIC & COMPANION-ANIMAL RESEARCH

Appendix A summarises dog-specific evidence relating to fermentable substrates, microbiome modulation, immune tolerance and established Ascophyllum nodosum use in canine nutrition, drawing primarily on controlled feeding studies and peer-reviewed veterinary literature.

A1. Ascophyllum and Oral / Dental Health in Dogs

Gawor, J.P. et al. (2018).

Effect of Ascophyllum nodosum supplementation on dental plaque and calculus accumulation in dogs. Journal of Veterinary Dentistry, 35(3), 178–184.

→ Demonstrates reduced plaque and calculus formation with Ascophyllum supplementation.

A2. Gut Microbiome, Prebiotics & Stool Quality in Dogs

Beloshapka, A.N. et al. (2013).

Fecal microbiota communities of healthy adult dogs fed raw meat-based diets with or without inulin or yeast cell wall extracts as assessed by 454 pyrosequencing. Federation of European Microbiological Societies, 84, 532-541.

→ Shows that fibre type (not just fibre level) drives microbial composition and SCFA production.

Middelbos, I.S. et al. (2007).

Evaluation of fermentable oligosaccharides in diets fed to dogs in comparison to fiber standards. Journal of Animal Science, 85, 3033-3044.

→ Highly relevant to green and red seaweed polysaccharides as fermentable fibres.

Swanson, K.S. et al. (2002).

Effects of supplemental fructooligosaccharides and mannanoligosaccharides on colonic microbial populations, immune function and fecal odor components in dogs. Journal of Nutrition, 132(Suppl. 6), 1717S–1719S. (Peer-reviewed symposium paper; expanded abstract.)

→ Establishes the link between fermentable fibres, microbiome shifts, and stool quality in dogs.

A3. Skin, Coat & Immune Health in Dogs

Marsella, R. (2011).

Advances in our understanding of canine atopic dermatitis. Veterinary Dermatology, 22(2), 111–121.

→ Supports the concept that gut health influences canine skin barrier and inflammation.

Puigdemont, A. et al. (2006).

Immunologic responses against hydrolysed soy protein in dogs with experimentally induced soy hypersensitivity. American Journal of Veterinary Research, 67, 3.

→ Demonstrates diet-driven immune modulation in dogs.

A4. Behaviour, Gut–Brain Axis & Wellbeing in Dogs

Bested, A.C. et al. (2013).

Intestinal microbiota, probiotics and mental health: from Metchnikoff to modern advances. Part II – contemporary contextual research. Gut Pathogens, 5:3.

→ Establishes biological plausibility of gut–brain axis relevance in dogs.

Zentek, J. et al. (2003).

Dietary effects on bifidobacteria and Clostridium perfringens in the canine intestinal tract. Journal of Animal Physiology and Animal Nutrition, 87, 397-407.

→ Supports the biological plausibility of gut comfort and fermentation in behavioural stability.

B. MARINE POLYSACCHARIDES & SEAWEED BIOACTIVES

RELEVANT TO DOGS AND OTHER MONOGASTRICS

The following studies are not dog-exclusive but describe mechanisms directly relevant to monogastric digestion, including fermentability, microbiome modulation, barrier integrity, immune signalling and antioxidant activity.

• O'Sullivan, L. et al. (2010).

Prebiotics from marine macroalgae for human and animal health applications. Marine Drugs, 8(7), 2038–2064.

→ Widely cited review framing marine polysaccharides explicitly as functional dietary fibres.

• Xie, C. et al. (2023).

A Review on Seaweeds and Seaweed-Derived Polysachharides: Nutrition, Chemistry, Bioactivities and Applications. Food Reviews International, 40, 1312-1347.

→ Comprehensive review of macroalgal polysaccharides, polyphenols and antioxidant compounds supporting their relevance to gut health and systemic physiology.

B1. Prebiotic Fermentation, SCFA Production & Microbiome Modulation

• Charoensiddhi, S. et al. (2022).

Gut microbiome modulation and gastrointestinal digestibility of polysaccharide-enriched seaweed extracts. Journal of Functional Foods, 96, 105204.

→ Demonstrates resistance to upper-GI digestion, selective fermentation by gut microbiota and significant increases in total SCFAs and butyrate production

• Cherry, P. et al. (2019).

Marine polysaccharides as prebiotics. Critical Reviews in Food Science and Nutrition, 59(1), 1–13.

→ Reviews fermentability of marine polysaccharides across monogastric and herbivorous species.

• Han, Z,-L. et al. (2019).

Evaluation of prebiotic potential of three marine algae oligosaccharides from enzymatic hydrolysis. Marine Drugs, 17, 173.

→ Demonstrates selective stimulation of butyrate-producing taxa and increased SCFA production

• Leiro, J.M. et al. (2007).

Immunomodulatory activity of sulphated polysaccharides from Ulva spp. International Immunopharmacology, 7(7), 879–888.

→ Demonstrates suppression of LPS-induced inflammatory signalling by ulvan-type polysaccharides.

• Seong, H., Bae, J.-H., Seo, J.-S., Kim, S.-A., Kim, T.-J., & Han, N.-S. (2019).

Comparative analysis of prebiotic effects of seaweed polysaccharides laminaran, porphyran, and ulvan using in vitro human fecal fermentation. Journal of Functional Foods, 57, 408–416

→ Demonstrates selective stimulation of fibrolytic and butyrate-producing taxa.

B2. Intestinal Barrier Integrity, Permeability & Mucosal Protection

• Yao, W. et al. (2023).

Polysaccharides from brown seaweed: physicochemical properties, intestinal absorption and beneficial effects on the intestinal barrier. Food Frontiers, 4, 1547-1560.

• Zhu, Z. et al. (2021).

Effects of sulphated galactans from red seaweeds on short-chain fatty acid production and gut microbial activity. Food Hydrocolloids, 112, 106320.

→ Supports SCFA production and fermentative effects of red seaweed galactans.

B3. Immune Modulation, Barrier Function & Tissue Integrity

• Ale, M.T. et al. (2011).

Anti-inflammatory activities of fucoidans from brown seaweeds. Carbohydrate Polymers, 85(3), 641–647.

→ Provides direct evidence for anti-inflammatory effects of brown seaweed fucoidans.

• Chen, Y et al. (2019).

Fucoidan from Undaria pinnatifida Ameliorates Epidermal Barrier Disruption via Keratinocyte Differentiation and CaSR Level Regulation. Marine Drugs, 17, 660.

→ Demonstrates fucoidan-mediated enhancement of keratinocyte differentiation and epidermal barrier function in vitro.

• Fitton, J.H. et al. (2015).

Fucoidan: a review of biological activities and therapeutic potential. Marine Drugs, 13, 5920–5946.

• Song, Y.S. et al. (2014).

Fucoidan Promotes the Reconstruction of Skin Equivalents. Korean Journal of Physiology & Pharmacology, 18(4), 327-331.

→ Demonstrates mechanistic support for tissue integrity roles.

B4. Polysaccharide-Polyphenol Interactions and Gut Modulation

• Lee, Z.J. et al. (2025).

Unravelling the bioactive interplay: seaweed polysaccharide, polyphenol and their gut modulation effect. Critical Reviews in Food Science and Nutrition, 65(2), 382-405.

→ Comprehensive review describing how interactions between seaweed polysaccharides and polyphenols enhance colonic delivery, SCFA production, microbiome modulation and anti-inflammatory effects.

• Lin, Q. et al. (2025).

Seaweed polysaccharides as potential Prebiotics: Rationale, factors, Prebiotic activity manifestations, gut health mechanisms and extraintestinal impacts. Trends in Food Science & Technology, 163, 105202.

→ High-level review describing structure–function relationships of seaweed polysaccharides, their interaction with gut microbiota, SCFA production, and downstream effects on barrier integrity and immune signalling.

B5. Structural Diversity, Bioaccessibility & Species Variability

• Pandey, A. et al. (2022)

Variability in macroalgal polysaccharide composition and functional implications. Journal of Cleaner Production, 363, 132456

→ Demonstrates that polysaccharide structure, molecular weight and sulfation patterns vary widely across species and conditions influencing fermentability and biological activity.

Zaitseva, O.O., Sergushkina, M.I., Khudyakov, A.N., Polezhaeva, T.V., & Solomina, O.N. (2022).

Seaweed sulfated polysaccharides and their medicinal properties. Algal Research, 68, 102885.

B6. Ruminant & Cross-Species Fermentation (Context only)

• Ahmed, M. et al. (2022).

Effects of brown seaweed supplementation on rumen fermentation and microbial ecology. Fermentation, 8, 504.

→ Demonstrates fermentation shifts, SCFA modulation, and microbial restructuring in large-herbivore systems.

• You, L. et al. (2020).

Brown seaweed polysaccharides: structure–function relationships in gut fermentation. International Journal of Food Science and Technology, 55, 1199-1206

→ Explains how molecular weight and sulfation influence fermentability and microbiome outcomes.

C. OXIDATIVE STRESS, PERFORMANCE & RECOVERY (Cross-Species Biological Context)

The underlying processes are relevant to metabolic resilience, immune balance and recovery.

• Finaud, J. et al. (2012).

Oxidative Stress. Sports Medicine, 36, 327-358.

• Michalak, I. et al. (2022)

Antioxidant effects of seaweeds and their active compounds on animal health and production – a review. Veterinary Quarterly, 42, 1, 48-67.

→ Reviews antioxidant mechanisms of seaweed-derived compounds and their relevance to oxidative balance, stress tolerance and health across animal production systems.

• Powers, S.K. & Jackson, M.J. (2008).

Exercise-induced oxidative stress: cellular mechanisms and impact on performance.

Physiological Reviews, 88, 1243–1276.

→ Supports antioxidant relevance to cross-species oxidative stress biology.

• Williams, C.A. et al. (2004).

Antioxidant supplementation and oxidative stress in exercising horses.

Journal of Nutrition, 134(8), 2081S–2084S.

→ Supports the relevance of antioxidant support during exercise and recovery.

D. GUT–BRAIN AXIS & SYSTEMIC EFFECTS (CROSS-SPECIES, HIGHLY RELEVANT)

• Cryan, J.F. & Dinan, T.G. (2012).

Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour.

Nature Reviews Neuroscience, 13, 701–712.

• Dalile, B. et al. (2019).

The role of short-chain fatty acids in microbiota–gut–brain communication.

Frontiers in Neuroscience, 13, 134.

• Pluske, J.R. et al. (2018).

Feed- and feed-additive-related aspects of gut health and development in animals.

Journal of Animal Science and Biotechnology, 9, 1–16.

→ Positions gut health as the central integrator of nutrition, immunity, and performance across species.

E. MULTI-SEAWEED & SYNERGISTIC APPROACHES

• Pereira, L. & Valado, A. (2025).

Beyond Nutrition: The Therapeutic Promise of Seaweed-Derived Polysaccharides Against Bacterial and Viral Threats. Marine Drugs, 23(10), Article 407.

• Tanna, B. & Mishra, A. (2018).

Metabolites from seaweeds and their applications.

Journal of Applied Phycology, 30, 1815–1828.

F. PRACTICAL FORMULATION & LONG-TERM FEEDING CONSIDERATIONS

• Teas, J. et al. (2004).

Variability of iodine content in seaweed and implications for dietary intake.

Journal of Food Composition and Analysis, 17(3–4), 421–432.

→ Demonstrates large natural variation in iodine content across seaweeds.

• National Research Council (2006).

Nutrient Requirements of Dogs and Cats. National Academies Press.

→ Authoritative reference on mineral tolerance, long-term feeding, and dietary balance in dogs.

G. WHY THESE REFERENCES MATTER FOR CANINE NUTRITION

Collectively, these studies support the core scientific framework of this white paper:

• Gut microbiome composition and fermentation quality are central to stool consistency, digestive tolerance, immune balance and behavioural wellbeing in dogs.

• Fermentable substrate structure, rather than fibre quantity alone, drives microbial and SCFA outcomes in canine systems.

• Established Ascophyllum nodosum use in dogs supports oral health but does not represent the full functional scope of marine macroalgae.

• Green and red seaweeds provide prebiotic, stool-stabilising, antioxidant and barrier-supporting functions that complement brown seaweeds.

• A multi-seaweed approach allows broader functional coverage while managing iodine exposure and formulation constraints.

• Cross-species marine polysaccharide research provides strong mechanistic support for gut-centred nutritional strategies in dogs when interpreted conservatively and species-appropriately.