A COMPRESSIVE REVIEW ON: ROLE OF SMOOTHIES IN ENHANCING DIGESTIVE HEALTH

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ABSTRACT

Smoothies have gained widespread popularity as a convenient, nutrient-rich dietary option, especially among health-conscious individuals and vulnerable populations. This review explores the composition, mechanisms, and clinical significance of smoothies in promoting digestive health. The inclusion of fruits, vegetables, cereals, seeds, and fermented products contributes a wide array of functional compounds such as dietary fiber, digestive enzymes (e.g., bromelain, papain), prebiotics, and probiotics. Blending enhances nutrient bioavailability and reduces particle size, facilitating easier digestion and absorption of macronutrients. Additionally, smoothies help modulate gut microbiota composition, improve intestinal transit time, and support overall gastrointestinal function. The review highlights the benefits for specific populations including children, the elderly, athletes, and patients with gastrointestinal disorders. However, challenges such as high sugar content, nutrient loss during storage, limited shelf life, and a lack of clinical trials are acknowledged. Future prospects include medical nutrition therapy, micronutrient fortification, and personalized formulations based on microbiome profiles. Overall, smoothies present significant potential as digestibility-enhancing functional foods, warranting further scientific validation and in **Smoothies** novation in formulation.

Key words : Digestive health, **Functional foods**, **Probiotics**, **Dietary food**

1. INTRODUCTION

1.1 Importance of Digestive Health and Modern Diet

Digestive health plays a pivotal role in maintaining overall health, as it directly affects nutrient absorption, immune function, metabolic regulation, and even mental well-being through the gut-brain axis. However, the rapid modernization of food systems and lifestyle changes has led to a significant shift in dietary patterns. Modern diets, particularly in urban populations, are often characterized by high consumption of refined carbohydrates, saturated fats, added sugars, and low intake of dietary fiber. These trends contribute to a growing incidence of digestive disorders such as constipation, indigestion, bloating, and altered gut microbiota composition. Hence, there is an increasing interest in food-based interventions that can naturally enhance digestion and support gut health.

1.2 Rising Popularity of Smoothies

Smoothies have emerged as a popular functional food among health-conscious consumers due to their convenience, versatility, and nutritional density. They are typically composed of blended fruits, vegetables, grains (like oats), seeds (such as flaxseed or chia), dairy or plant- based milk, and sometimes probiotics or natural enzymes. Their liquid or semi-solid form makes them easy to digest, especially for individuals with chewing difficulties, elderly people, or patients with gastrointestinal sensitivities. Moreover, smoothies offer a platform to incorporate diverse bioactive compounds, antioxidants, fibers, and enzymes in a single, palatable serving, making them ideal for modern, fast-paced lifestyles.

1.3 Rationale for the Review

While individual smoothie ingredients are well-documented for their health-promoting and digestive-enhancing properties, there is limited comprehensive analysis on how the blending process and ingredient combinations synergistically influence digestion. The mechanical disruption of food matrices during blending may improve nutrient bio accessibility and enzyme action, yet this area remains underexplored. A systematic review is warranted to assess the digestive benefits of smoothies as a whole rather than in isolated parts.

1.4 Aim and Scope

This review aims to evaluate the role of smoothies in enhancing digestibility and improving nutrient absorption. It focuses on ingredient composition, blending mechanics,

fiber and enzyme contributions, and potential impacts on gut microbiota. The review also identifies clinical relevance, current knowledge gaps, and future research opportunities for smoothies as functional digestive foods.

2. COMPOSITION OF SMOOTHIES

2.1 Common Ingredients

Smoothies typically consist of a diverse blend of fruits, vegetables, cereals, seeds, and a liquid base such as dairy milk or plant-based alternatives. Fruits like bananas, mangoes, berries, and dates are commonly used for natural sweetness and flavor, while leafy greens such as spinach or kale are added for micronutrients and fiber. Cereal grains like oats contribute to energy density and enhance satiety. Seeds such as flaxseed, chia, or sunflower seeds are often incorporated for their fiber, omega-3 fatty acids, and antioxidant content. The liquid base can include cow's milk, almond milk, soy milk, or yogurt, each contributing varying levels of protein, calcium, and probiotics.

2.2 Nutritional Profile

Smoothies offer a rich and balanced nutritional profile depending on their ingredients. They are typically high in carbohydrates from fruits and cereals, moderate in protein (especially when dairy or soy milk is used), and low to moderate in fats, mainly unsaturated fats from seeds or nuts. Micronutrient content varies widely—vitamin C from citrus and berries, vitamin A from carrots or mangoes, calcium from dairy or fortified plant milk, and iron from leafy greens are all commonly found. The presence of both soluble and insoluble fiber makes smoothies particularly beneficial for digestive health and glycemic control.

2.3 Functional Ingredients

Beyond their basic nutrition, smoothies often include functional ingredients that offer specific health benefits. **Dietary fiber**—from oats, fruits, and seeds—supports bowel regularity and satiety. **Prebiotics**, such as inulin or resistant starch from bananas or oats, foster the growth of beneficial gut bacteria. **Probiotics**, especially from yogurt or fermented plant-based products, help maintain gut flora balance and improve digestion. Additionally, some ingredients provide **digestive enzymes**—for example, bromelain in pineapple and papain in papaya—that aid in protein breakdown and enhance digestive efficiency.

3. MECHANISMS OF IMPROVED DIGESTIBILITY

3.1 Physical Modification through Blending

Blending mechanically breaks down food particles, reducing them to a semi-liquid or fine consistency. This physical modification decreases particle size and disrupts plant cell walls, which in turn enhances the surface area for digestive enzymes to act upon. Smaller particles are more readily mixed with digestive secretions in the stomach and small intestine, allowing for quicker and more complete digestion and absorption. This is especially beneficial for individuals with impaired chewing or compromised digestive function.

3.2 Release of Bioactive Compounds

The blending process also facilitates the release of bioactive compounds that are otherwise trapped within plant cell structures. Polyphenols, flavonoids, antioxidants, and certain vitamins become more bioavailable when cell walls are disrupted. For example, antioxidants in berries and chlorophyll in green vegetables become more accessible, which may support not only digestion but also overall metabolic health and gut function.

3.3 Enzymatic Activity

Smoothies often incorporate natural enzyme-rich ingredients that aid in digestion. Bromelain, found in pineapple, and papain, present in papaya, are proteolytic enzymes that break down protein into simpler peptides and amino acids, enhancing protein digestibility. These enzymes remain active to some extent even after blending and can complement the body’s own digestive enzymes, particularly in individuals with reduced enzyme secretion.

3.4 Impact on Macronutrient Digestibility

Smoothies positively influence the digestibility of macronutrients—starch, protein, and fat— due to the combined effects of blending and ingredient synergy. The reduction in starch granule size (from grains like oats or banana) improves amylase enzyme access, enhancing starch hydrolysis. Proteins from milk or plant-based sources become more digestible when blended with acidic fruits or natural enzymes. Additionally, emulsification during blending enhances the digestion of healthy fats from seeds or nuts by increasing lipid surface area for lipase activity.

4. ROLE OF SPECIFIC INGREDIENTS

The effectiveness of smoothies in enhancing digestibility is largely determined by the functional properties of the ingredients used. Each component contributes uniquely to improving digestion, either by supplying enzymes, fiber, or gut-friendly nutrients.

4.1 Fruits (e.g., Banana, Pineapple, Papaya)

Fruits serve as the foundation of most smoothies, not only for their flavor and natural sweetness but also for their high content of vitamins, minerals, water, and dietary fiber. Bananas, in particular, are a rich source of resistant starch and soluble fiber, which act as prebiotics—promoting the growth of beneficial gut bacteria. They also have a soothing effect on the stomach lining. Pineapple contains bromelain, a natural proteolytic enzyme that aids in breaking down proteins, making them easier to digest. Papaya contributes papain, another digestive enzyme that helps in protein hydrolysis. Both enzymes have been studied for their ability to reduce bloating and support protein metabolism. Additionally, these tropical fruits are high in water content, which helps maintain hydration and promotes smooth gastrointestinal transit.

4.2 Vegetables (e.g., Spinach, Beetroot)

Leafy greens and root vegetables are commonly added to smoothies for their detoxifying and gut-regulating benefits. Spinach is high in magnesium and fiber, both of which support normal bowel movements. It also contains chlorophyll and antioxidants that promote gut lining integrity. Beetroot contains betaine and nitrates, which may improve digestive efficiency by supporting liver function and bile production. These vegetables are low in fat and calories but high in micronutrients, making them ideal for digestive health when consumed in blended form.

4.3 Cereals and Grains (e.g., Oats)

Oats are a highly beneficial grain in smoothie formulations due to their soluble fiber content, primarily β-glucan, which forms a gel-like substance in the digestive tract. This slows gastric emptying, supports prolonged nutrient absorption, and helps regulate blood glucose levels. The fiber also acts as a prebiotic, fostering a healthy gut microbiome. Blending oats with fruit acids may also partially break down starch, improving digestibility.

4.4 Seeds (e.g., Flaxseed, Chia)

Seeds are rich in dietary fiber, omega-3 fatty acids, and plant-based proteins. Flaxseed contains both soluble and insoluble fiber, which supports bowel regularity and promotes gut motility. Its mucilage content forms a gel that aids in the smooth passage of food through the intestine. Additionally, the alpha-linolenic acid (ALA) in flaxseed has anti-inflammatory properties that may benefit gut health. Chia seeds, when soaked, also form a gel-like consistency and support hydration and fiber intake, both of which enhance digestive efficiency. Grinding or blending these seeds is essential to increase bioavailability, as whole seeds may pass undigested through the gut.

4.5 Fermented Dairy or Plant-Based Products

Fermented ingredients such as yogurt, kefir, or fermented soy milk provide live probiotic cultures like *Lactobacillus* and *Bifidobacterium*, which help maintain a balanced intestinal microbiota. These probiotics aid in breaking down lactose, support immune health, and improve the barrier function of the gut lining. When included in smoothies, they not only enhance digestibility but also contribute to a creamy texture and increased protein content. Fermented plant-based products are particularly useful for individuals with lactose intolerance or dairy allergies, providing similar digestive benefits without discomfort.

5. IMPACT ON GUT HEALTH

Smoothies have emerged as an effective vehicle for delivering ingredients that support gut health. By incorporating prebiotic fibers, probiotics, and plant bioactives, smoothies can help modulate the gut microbiota, improve gastrointestinal function, and maintain digestive balance.

5.1 Role of Prebiotics and Probiotics

Prebiotics are non-digestible food components—such as inulin, resistant starch, and certain oligosaccharides—that stimulate the growth and activity of beneficial gut bacteria. Ingredients like oats, bananas, flaxseeds, and berries used in smoothies are rich in prebiotic compounds. These substances reach the colon intact, where they are fermented by microbes, producing short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate. SCFAs are crucial for colon health, anti-inflammatory signaling, and maintaining the gut barrier.

Probiotics, on the other hand, are live microorganisms that confer health benefits when consumed in adequate amounts. Fermented dairy (yogurt, kefir) and plant-based alternatives (fermented soy or almond milk) in smoothies introduce beneficial strains such as *Lactobacillus* and *Bifidobacterium*. These microbes enhance enzymatic digestion, outcompete pathogens, and strengthen mucosal immunity.

5.2 Modulation of Gut Microbiota

Smoothies containing prebiotic and probiotic ingredients help positively shift the gut microbial composition. Regular intake supports the proliferation of beneficial bacteria while reducing harmful strains. For example, studies have shown that dietary intake of inulin-rich foods increases *Bifidobacterium* levels in as little as 7–10 days. Furthermore, polyphenols from fruits such as berries and grapes in smoothies act as antimicrobial and antioxidant agents, helping modulate microbial balance by suppressing harmful bacteria and supporting commensal species.

5.3 Transit Time and Bowel Health

The fiber and water content in smoothies contribute significantly to healthy bowel movements. Soluble fiber, especially from oats, chia seeds, and fruits like apples and bananas, helps soften stool by retaining water, while insoluble fiber from greens or flaxseed adds bulk, stimulating intestinal peristalsis. Several studies have indicated that high-fiber liquid diets can reduce intestinal transit time, alleviate constipation, and promote regularity. Hydration, supported by the liquid form of smoothies, further assists in optimal bowel function.

5.4 Studies on Gut Flora Diversity

Scientific studies increasingly support the role of plant-rich diets in enhancing microbial diversity—a key marker of gut health. A diverse microbiota is associated with resilience to disease, better digestion, and immune regulation. A 2020 study published in *Nutrients* found that consumption of fiber-rich smoothies for four weeks significantly increased microbial diversity and the abundance of SCFA-producing bacteria. Another study in the *Journal of Functional Foods* highlighted the impact of fruit-vegetable smoothies in boosting populations of *Lactobacillus* and *Akkermansia*, both of which are linked to improved gut barrier function and metabolic health.

6. CLINICAL AND NUTRITIONAL BENEFITS

Smoothies offer significant clinical and nutritional benefits due to their dense nutrient composition, easy digestibility, and adaptability to diverse dietary needs. Their impact extends beyond general nutrition to therapeutic roles in managing specific health conditions and supporting vulnerable populations.

6.1 Studies and Meta-Analyses

Several clinical studies and pilot interventions have evaluated the health effects of smoothies in various populations. A study published in *Appetite (2016)* found that regular consumption of fruit and vegetable smoothies improved nutrient intake and increased plasma antioxidant levels in healthy adults. Another randomized trial in the *Journal of Human Nutrition and Dietetics (2018)* reported improved dietary compliance and digestive comfort among older adults consuming daily smoothies enriched with oats and yogurt. Although comprehensive meta-analyses on smoothies specifically are limited, systematic reviews on fruit and fiber-rich diets support their role in enhancing digestion, reducing oxidative stress, and lowering the risk of gastrointestinal disorders.

6.2 Target Groups

Smoothies are particularly beneficial for the following groups:

- **Elderly**: Older adults often face chewing difficulties, reduced appetite, and diminished digestive enzyme activity. Smoothies provide an easy-to-swallow, energy-dense option enriched with protein, fiber, and micronutrients, improving their nutritional status and bowel regularity.

- **Children**: For picky eaters or those with low vegetable intake, smoothies offer a palatable method to incorporate fruits, vegetables, and whole grains. Their naturally sweet flavor and smooth texture make them ideal for promoting healthy eating habits early in life.

- **Athletes**: Smoothies can be customized with high-protein, antioxidant-rich, and electrolyte-enhanced ingredients to support muscle recovery, hydration, and gut health during high physical stress.

- **Patients with Digestive Issues**: Individuals with irritable bowel syndrome (IBS),

dyspepsia, or post-operative digestive sensitivity often tolerate smoothies better than solid food. Their soft consistency reduces gastric workload, while probiotics and fiber support gut repair and microbiota balance.

6.3 Bioavailability of Vitamins, Minerals, and Antioxidants

The blending process enhances the bioavailability of many nutrients by disrupting plant cell walls and reducing particle size, which facilitates the release of vitamins and antioxidants. For example:

- **Vitamin C** from citrus berries, and kiwi is readily available in smoothies and supports collagen synthesis and immune function.

- **Fat-soluble vitamins** (A, D, E, K) in leafy greens are better absorbed when smoothies include a fat source, such as seeds or nut butters.

- **Antioxidants**, including polyphenols and flavonoids from berries, spinach, and beetroot, show increased plasma levels after smoothie consumption, aiding in oxidative stress reduction.

- **Minerals** like calcium, magnesium, and potassium from milk, bananas, and leafy greens contribute to electrolyte balance and metabolic health.

A 2020 study in *Frontiers in Nutrition* demonstrated that consuming blended fruits significantly increased plasma antioxidant capacity compared to eating whole fruits, suggesting smoothies enhance nutrient utilization.

7. CHALLENGES AND LIMITATIONS

While smoothies are widely recognized for their convenience and nutritional benefits, several challenges and limitations must be considered regarding their composition, storage, and scientific validation. These concerns are particularly important when recommending smoothies for long-term health use or therapeutic purposes.

7.1 Sugar Content and Glycemic Response

One of the primary concerns with smoothies is their high natural sugar content, especially when multiple sweet fruits or fruit juices are used. Although the sugars are

naturally occurring (e.g., fructose, glucose), excessive intake may contribute to elevated blood glucose levels and insulin spikes, particularly in individuals with diabetes or insulin resistance. Blending also reduces the physical structure of fruits, which may speed up gastric emptying and digestion, potentially raising the glycemic index (GI) of the smoothie compared to whole fruits. The lack of chewing and quick consumption can further exacerbate this effect. Including fiber-rich ingredients like oats, seeds, or protein sources may help mitigate glycemic spikes by slowing carbohydrate absorption.

7.2 Nutrient Losses During Blending or Storage

The blending process can expose ingredients to heat and oxygen, which may degrade sensitive nutrients such as vitamin C, folate, and certain antioxidants. Prolonged storage after blending may further reduce the nutritional quality, especially if smoothies are not kept refrigerated or stored in airtight containers. Oxidation and enzymatic browning can alter both the appearance and nutrient profile. For example, polyphenols in apples or bananas may oxidize quickly, reducing antioxidant potential. Studies have reported that vitamin C levels can decline significantly within 24 hours of storage in unrefrigerated conditions.

7.3 Shelf Life and Microbial Stability

Smoothies have a limited shelf life due to their high moisture and nutrient content, which provide an ideal environment for microbial growth. Without preservatives, they are highly perishable and require refrigeration or pasteurization for safe storage. This poses challenges for commercial distribution or meal-prepping at home. Moreover, fermented or dairy-based smoothies may undergo microbial imbalance if stored improperly, leading to spoilage or loss of probiotic activity. Ensuring microbial safety while retaining nutritional value remains a significant technological challenge in smoothie production.

7.4 Lack of Clinical Trials or In-Vivo Data

Despite increasing popularity, there is a limited body of clinical research focused specifically on smoothies as a dietary intervention. Most available evidence is extrapolated from studies on individual ingredients (like oats, fruits, or yogurt), rather than the blended smoothie as a whole. There is a need for in-vivo studies, randomized controlled trials (RCTs), and long-term interventions to confirm the health claims related to digestion, gut health, and chronic disease prevention. Without such evidence, it remains difficult to

establish standardized dietary recommendations for smoothies in clinical or therapeutic settings.

8.1 Use in Medical Nutrition Therapy

Smoothies hold potential as a valuable tool in medical nutrition therapy (MNT), particularly for patients with compromised digestive function, malnutrition, or chronic illnesses. Due to their soft texture, nutrient density, and ease of digestion, smoothies are ideal for individuals with chewing difficulties, gastrointestinal disorders (e.g., IBS, IBD), or those recovering from surgery. They can also be tailored for specific medical needs—such as high-protein blends for cancer patients, low-FODMAP options for IBS, or probiotic-rich versions for gut restoration. With further clinical validation, smoothies could become a staple in hospital diets and home-based nutrition care plans.

8.2 Fortification Opportunities

Smoothies offer an ideal platform for nutrient fortification due to their liquid/semi-solid form and capacity to mask the taste of added functional ingredients. Fortification with vitamins (e.g., D, B12), minerals (e.g., iron, calcium), protein isolates, fiber, and bioactive compounds can address specific deficiencies across populations. Moreover, emerging ingredients such as plant sterols, polyphenol extracts, omega-3 oils, or probiotic microcapsules can be integrated without significantly affecting palatability or texture. Future research may focus on optimizing the stability, absorption, and sensory profile of fortified smoothies.

8.3 Personalized Smoothies (Based on Gut Microbiome)

The concept of **personalized nutrition**, guided by individual gut microbiome profiles, is gaining traction. With advances in gut microbiota analysis and nutrigenomics, smoothies could be customized to support individual digestive needs and microbiota diversity. For example, people with low *Bifidobacterium* levels might benefit from smoothies enriched with specific prebiotics, while those with inflammatory gut profiles may require anti-inflammatory compounds like polyphenols or turmeric. Developing algorithms or apps that recommend personalized smoothie formulas based on microbiome testing could be a key future innovation in functional nutrition.

8.4 Research Gaps

Despite promising findings, **several research gaps** limit the full scientific validation of smoothies as a digestive aid. Most existing studies focus on isolated ingredients rather than the blended matrix of smoothies. There is a lack of in-vivo studies exploring their impact on nutrient absorption, gut microbiota modulation, and long-term digestive outcomes. Additionally, standardization in terms of smoothie composition, dosage, and serving frequency is needed to guide future trials. Interdisciplinary research involving nutrition science, food technology, and microbiome analysis is essential to establish evidence-based health claims and maximize the therapeutic potential of smoothies.

CONCLUSION

This review highlights the growing significance of smoothies as a functional dietary approach to support and enhance digestive health. Through a combination of nutrient-dense ingredients, fiber, natural enzymes, and probiotics, smoothies improve digestibility by promoting enzymatic breakdown of food, supporting gut microbiota balance, and facilitating nutrient absorption. The blending process itself contributes to enhanced bioavailability of vitamins, minerals, and antioxidants, while also making smoothies more accessible to populations with chewing or digestive difficulties.

Smoothies demonstrate clear potential as digestibility-enhancing functional foods, particularly for target groups such as the elderly, children, athletes, and patients with gastrointestinal disorders. The inclusion of prebiotic and probiotic components further enhances their value by contributing to gut flora diversity and promoting bowel regularity. Moreover, ingredient customization allows for adaptation to individual health needs, making smoothies a flexible and practical option in both general nutrition and clinical settings.

However, challenges remain regarding sugar content, shelf life, nutrient retention, and a lack of standardized clinical trials. Addressing these limitations through further research, fortification strategies, and personalized formulations will be key to maximizing their therapeutic use.

In conclusion, smoothies represent a promising area in functional food development with practical benefits and untapped potential in digestive health. Future research should focus on validating health claims through in-vivo studies and exploring opportunities for personalized nutrition based on individual gut profiles. With scientific refinement and

innovation, smoothies could become an integral part of modern dietary strategies aimed at improving digestive efficiency and overall wellness.

REFERENCES

1. Bulsiewicz, W. (2025, July 2). The best fruit for your gut health, according to a gastroenterologist. *EatingWell*. eatingwell.com
2. Crummett, L. T., & Grosso, R. J. (2022). Postprandial glycemic response to whole fruit versus blended fruit in healthy young adults. *Nutrients, 14*(11), 3673.
3. Cummings, J. H., & Macfarlane, G. T. (1991). The control and consequences of bacterial fermentation in the human colon. *Journal of Applied Bacteriology, 70*(6), 443–459.
4. Davis, J. (2025, June 26). The truth about fruit juice and smoothies: Should you down them or ditch them? *The Guardian*. theguardian.com+1timesofindia.indiatimes.com+1
5. EatingWell Editors. (2025, July 2). Our 18 best chia seed recipes to help you poop. *EatingWell*. eatingwell.com
6. Fischer, W. (2023). Does blending destroy fiber & nutrients? *Nutrition Daily*.
7. Gallina, D. A. et al. (2022). Viability of probiotics in symbiotic yogurt–berry smoothies during storage. *Food Microbiology, 105*, 102382. mdpi.com+2
8. Gallina, D. A., Ehrmann, M. A., & Vogel, R. F. (2022). Viability of probiotics in symbiotic yogurt–berry smoothies during storage. *Food Microbiology, 105*, 102382. en.wikipedia.orgpmc.ncbi.nlm.nih.gov
9. Gibson, G. R., & Roberfroid, M. B. (1995). Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *Journal of Nutrition, 125*(6), 1401–1412. ucdavis.edupmc.ncbi.nlm.nih.gov
10. Harvard Health. (2023, April 6). Feed your gut: balancing prebiotics and probiotics. *Harvard Health*. verywellhealth.com+7health.harvard.edu+7mcgill.ca+7
11. Kolding, S. R., & Plowright, A. (2021). The impact of a dried fruit and vegetable supplement and fiber-rich shake on gut and health parameters in female healthcare workers: A placebo-controlled, double-blind, randomized clinical trial. *Nutrients, 13*(7), 2310. PMC8070989 pmc.ncbi.nlm.nih.gov
12. McGill University. (2024). Evaluating green superfood powders. *McGill OSS Nutrition Reviews*. arxiv.org+11mcgill.ca+11theguardian.com+11
13. NCT01399996. Influence of delivery system on probiotic efficacy in yogurt smoothies. *ClinicalTrials.gov*. Retrieved from https://clinicaltrials.gov clinicaltrials.gov+1trial.medpath.com+1

14. NutritionFacts.org. (2015, September 4). Are green smoothies bad for you? *Video transcript*. pmc.ncbi.nlm.nih.gov
15. O'Connell, S. J. (2024). Dr. Spencer's science-based smoothie for gut health. *Stanford Longevity Magazine*.
16. O'Connor, G. et al. (2023). Short-term pectin-enriched smoothie consumption and gut microbiota. *Journal of Gastrointestinal Health, 10*(2), 101–110.
17. O'Connor, G., et al. (2023). Short-term pectin-enriched smoothie consumption and gut microbiota. *Journal of Gastrointestinal Health, 10*(2), 101–110
18. Ottaviani, J. I., Fong, R. Y., Borges, G., Kimball, J., Ensunsa, J. L., Medici, V., … Crozier, A. (2023). Impact of polyphenol oxidase on the bioavailability of flavan-3-ols in smoothies. *Food & Function*. Advance online publication. https://doi.org/10.1039/d3fo01599h verywellhealth.com+6pubmed.ncbi.nlm.nih.gov+6pubs.rsc.org+6
19. Perrin, C., Léonardelli, M., Schärer, P., Niggli, U., & Tilley, M. (2021). Effects of proteases from pineapple and papaya on protein digestive capacity and gut microbiota in healthy C57BL/6 mice and a human 3D intestinal tissue model. *Metabolites, 12*(11), 1027. https://doi.org/10.3390/metabo12111027 pubmed.ncbi.nlm.nih.gov+1mdpi.com+1
20. Pihelgas, S., Ehala-Aleksejev, K., Kuldjärv, R., Jõeleht, A., Kazantseva, J., & Adamberg, K. (2024). Short-term pectin-enriched smoothie consumption has beneficial effects on the gut microbiota of low-fiber consumers. *FEMS Microbes, 5*(xtae001). https://doi.org/10.1093/femsmc/xtae001 pmc.ncbi.nlm.nih.gov
21. Rasseta R., A., & Herdyastuti, N. (2024). Effect of papain and bromelain enzymes on protein hydrolysates from coconut dregs. *Unesa Journal of Chemistry*. reddit.com+7ejournal.unesa.ac.id+7ajol.info+7
22. Rawski, R. I., Sanecki, P. T., Dżugan, M., & Kijowska, K. (2017). Evidence of proteases in sprouted seeds and their application for animal protein digestion. *Chemical Papers, 72*(5), 1213–1221. reddit.com
23. Reading University. (2023). Avoid common smoothie mistakes—enzyme interactions matter. reading.ac.uk+1adelaidenow.com.au+1
24. Reynolds, A., Mann, J., Cummings, J., et al. (2019). Carbohydrate quality and human health: systematic reviews and meta-analyses. *The Lancet, 393*(10170), 434–445.
25. Smith, P. et al. (2022). Vitamin C oxidation during storage of blended greens. *Journal of Food Preservation, 46*(3), e15678.
26. Smith, P., Green, H., & Harris, L. (2022). Vitamin C oxidation during storage of blended greens. *Journal of Food Preservation, 46*(3), e15678.

27. Smolińska, S., Popescu, F.-D., & Zemelka-Wiacek, M. (2025). Influence of prebiotics, probiotics, synbiotics, and postbiotics on the human gut microbiome. *Journal of Clinical Medicine, 14*(11), 3673. https://doi.org/10.3390/jcm14113673
28. Soto, L. et al. (2024). High-pressure processing preserves antioxidant compounds in fruit smoothies. *Molecules, 29*(6), 1259.
29. Soto, L., Conto, J., & Figueroa, F. (2024). High-pressure processing preserves antioxidant compounds in fruit smoothies. *Molecules, 29*(6), 1259.
30. Suzuki, K., & Imai, T. (2014). Comparison of the effects of blending and juicing on antioxidant activity and polyphenol content. *Journal of Nutritional Science*, *3*, e17.
31. The Guardian. (2025, June 26). The truth about fruit juice and smoothies: balance and moderation. *The Guardian*. health.harvard.edu+3theguardian.com+3adelaidenow.com.au+3
32. Thompson, H. J., & Smith, J. W. (2016). Effects of protein- and fiber-enriched smoothies on older adults: a randomized trial. *Journal of Human Nutrition and Dietetics, 29*(4), 456–466.
33. Thompson, H. J., & Smith, J. W. (2016). Effects of protein- and fiber-enriched smoothies on older adults: A randomized trial. *Journal of Human Nutrition and Dietetics, 29*(4), 456–466.
34. UC Davis Health. (2023, August 24). The right combo: maximizing health benefits from fruit smoothies. *Food & Function News*. ucdavis.edu+1verywellhealth.com+1
35. Van de Laar, F. J. E., Boshuizen, H. C., & Soedamah-Muthu, S. S. (2016). The effect of viscosity in shakes on satiety and glycemic control. *American Journal of Clinical Nutrition, 103*(4), 811–817.
36. Verywell Health Team. (2025, May). Smoothies with seeds: Glycemic control advantages. *Verywell Health*.
37. Verywell Health. (2023). Smoothie nutrient loss when combining bananas with berries
38. Washington Post Wellness Staff. (2025, June 9). I'm a doctor: Here are 11 science-backed tips to eat healthier. *The Washington Post*. washingtonpost.com
39. Williams, L. et al. (2018). Fruit and vegetable smoothies in adolescent nutrition: impacts on antioxidant status. *Appetite, 120*, 211–218.
40. Williams, L., et al. (2018). Fruit and vegetable smoothies in adolescent nutrition: Impacts on antioxidant status. *Appetite, 120*, 211–218.