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SAPONINS: REDEFINING GLUTEN-FREE FOODS

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INTRODUCTION

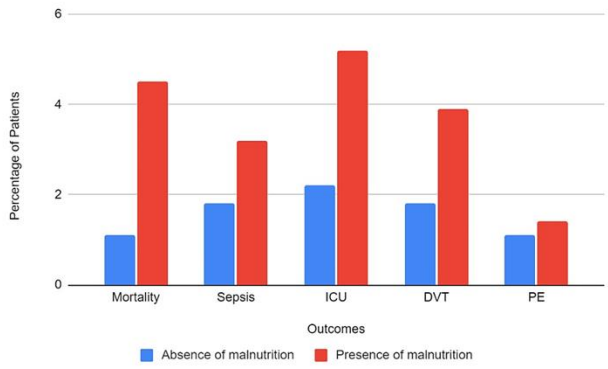


Figure 1: The table demonstrates the prevalence and impact of malnutrition in hospitalisations among coeliac disease patients in America. One reason is that there is a lack of gluten-free foods are not available (Bains, et al., 2023).

One in seventy people in Australia has coeliac disease and about 11% follow a gluten-free diet, so having gluten-free options is very important. Scientists from the University of Hohenheim in Stuttgart, Germany have proven a new protein alternative to gluten – natural saponins (University of Hohenheim, 2023). The protein, commonly found in quinoa, oats, soybeans, peanuts and spinach, are naturally occurring structurally and functionally diverse phytochemicals. For celiac-patients (figure 1), this new development is revolutionary as it will widen horizons in food availability and the taste of gluten-alternative rich foods. However, saponins are antinutrients, meaning they interfere with the digestion and absorption of nutrients. In this task of nutritional science as a human endeavour, the applications and limitations of using natural saponins as a protein alternative to gluten and its potential impact on society.

NUTRITIONAL SCIENCE BACKGROUND

Saponins are triterpene glycosides[1], are bitter tasting organic phytochemicals are naturally found in many plant parts. They include a glycone[2] and an aglycone[3] (figure 2). Saponins are found in many legumes, ginseng roots, sunflower seeds, quinoa, and spinach leaves. When they enter the small intestine, saponins absorbs into the small intestinal mucosal cells and increase their permeability, making it harder to absorbs food nutrients into the bloodstream. Thus, adds a sense of satiety to the stomach. However, the saponins irritates the membranes of the respiratory and digestive tract. They also bind to certain minerals like iron and zinc and make them less likely to get absorbed. Although, because they add to the permeability of the gut, saponins have potential health benefits such as lowering cholesterol, blood glucose and cancer risk.

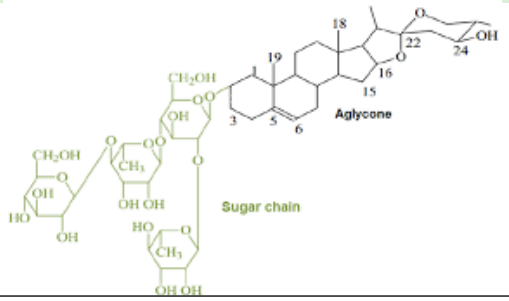


Figure 2: The general chemical compound of a triterpenoid saponin. The sugar chain is the glycone (Ligor, et al., 2021).

[1] Triterpene glycosides are exogenous origin substances that affect warm-blooded animals' physiological activity. They affect the organisms and their organ's metabolism and function.

[2] The sugar group is known as a glycone and the non-sugar group is known as an aglycone in a glycoside.

[3] An aglycone is a molecule which a sugar group (glycone) is bonded to in a glycoside.

Prof. Dr. Mario Jekle, lead scientist at the University of Hohenheim first extracted samples from food sources and analysed and characterised the individual compounds. Their foaming properties in aqueous solution were tested. Favourable samples were trialled in a standard dough recipe and during baking, the structure and stability of the resulting foam were examined (figure 4). Gas bubbles not the right size or stability would coalesce or collapse as the dough expanded, creating a dense and heavy bread after baking. Finding the right saponins is thus crucial to obtain the correct bread texture (figure 3). For saponins, many factors affect how these bubbles are stabilised, including the branching, composition and length of the sugar chain within it and the molecules' orientation on the dough surface (University of Hohenheim, N/A).

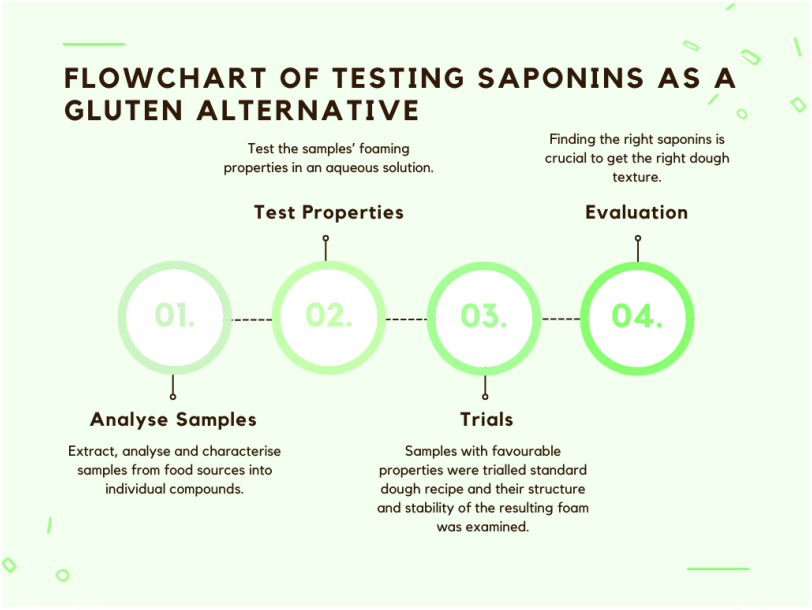
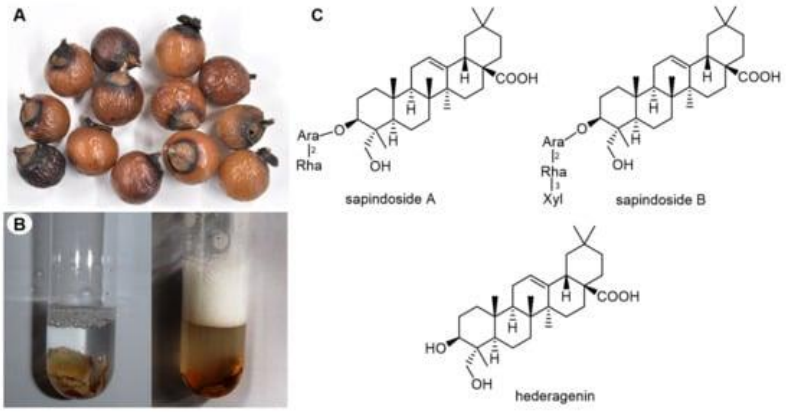


Figure 3 (above): A flowchart detailing how Dr. Jekle examines saponins' qualities to get the perfect texture of a gluten-free dough.
Figure 4 (below): Walnuts as the food source of saponins (A), The saponins' foaming qualities before and after shaking it. (B). The different types of saponins' chemical compounds and their aglycone, hederagenin (C).



APPLICATIONS AND LIMITATIONS

APPLICATIONS

Gluten gives structure to the bread mixture and stability such that it does not collapse prematurely. It has a froth that perfectly stabilises the interface between gas bubbles and dough. However, what other alternatives fail to do is stabilise the formation of an airy dough like gluten can. Now, with new research, saponins do have gluten-like properties and can support the formation of an airy dough, to replace gluten. The saponins can produce a soapy lather when mixed with water which means it can froth. Saponins can form a durable film that effectively traps the gas bubbles and withstands the stresses of dough expansion. It can sometimes also enrich it with dietary fibre. Saponins in gluten-free foods can accurately imitate the look and taste of the same food with gluten.

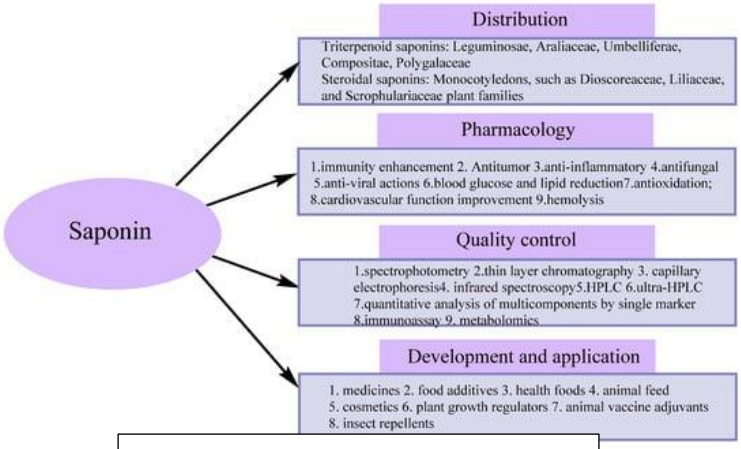


Figure 5: Saponin mind map; with distribution or the types of saponins, the benefits they have in pharmacology, analytical methods to test their quality and other applications of saponins tried previously (Wang, et al., 2022).

Saponins have many health benefits – they add to the permeability of the small intestines. This indicates absorbing glucose and lipids into the bloodstream will be harder. Since it takes longer for the body to use these macronutrients, it provides the body with greater levels of energy. A feeling of satiety is thus created, the blood glucose level sustained and lower saturated fats causing lower levels of cholesterol. The lower levels of cholesterol mean lower cardiovascular disease and cancer risks due to the blood vessels widening (figure 5).

Figure 6: Foods containing gluten that saponin can be imitated (Jordan Stachel, 2022).

Although the gluten-free range is wide, they cannot exactly replicate all foods containing gluten like bread, finger buns, beer, pasta, tomato sauce and cereals (figure 6). With this new discovery, saponin could be extracted from samples, replace gluten in the food procedure, and made into to imitate the taste and texture of these foods. This helps to widen the food horizons of coeliacs, helping them to enjoy more foods.

LIMITATIONS

The health concerns of saponins have been the subject of dispute among experts; some contend that the risks outweigh the benefits. They can all agree, though, that eating a lot of saponin-rich foods is not a good idea. According to Heidi Hingtgen and Dr Robert Kiltz, saponins are toxic chemicals that protect plants from bacteria, insect and fungal pathogens thus causing some toxicity to the body. Severe poisoning is rare but some gastrointestinal side effects may occur like abdominal pain, abdominal distension, diarrhea, bloating, nausea and vomiting. More severe cases can lead towards increased intestinal permeability, also known as leaky gut (figure 7). They interfere with the mucosa lining of the intestines because they bind to cholesterol. The leaky intestinal cell membrane allows molecules and water to enter and exit the bloodstream freely, resulting in ruptured intestinal cell membrane.

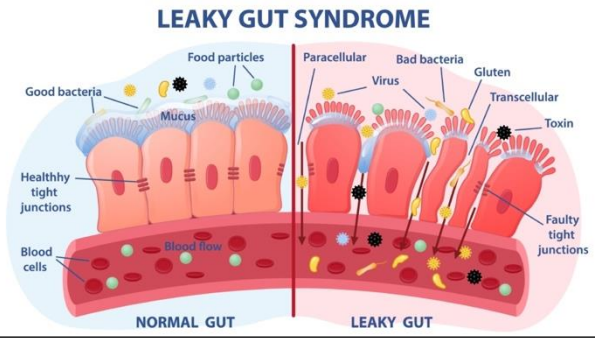


Figure 7: A diagram describing the difference between a normal gut and a leaky gut (Hingtgen, 2023).

Saponins can destroy red blood cells by dissolving their membranes and allowing free haemoglobin to be released into the bloodstream in a process called haemolysis. Leaky gut cause inflammation and can lead to some diseases and autoimmune disorders. Anaemia may result from red blood cell deterioration. Red blood cell death caused by saponin is more common in diseases such type 2 diabetes, sepsis, malaria and sickle cell disease (Hingtgen, 2023).

Saponin-rich foods can raise the risk of deficiencies in iron, magnesium, and vitamin A because they inhibit the absorption of vitamins and minerals. Protein digestion may be hampered by their potential to damage digestive enzymes. While certain saponins promote fertility, others might also lead to infertility. While certain saponins function as spermicides, others enhance sperm motility and development. Because of their similar molecular structure to reproductive hormones, they compete with hormones for receptor space. This could interfere with the levels of hormones needed for reproduction (Hingtgen, 2023). Coeliac disease patients occasionally need to avoid foods where saponin replaces gluten, even if these alarming numbers only apply to large consumption of foods high in saponins.

Saponin-rich foods like quinoa has already been made into flour to substitute for plain flour. Although has health benefits and can be eaten by coeliacs, quinoa bread is incredibly expensive. With prices averaging $9.95 for quinoa-bread as compared to plain bread for $4.67, this could reflect the prices of saponin-bread when they are introduced to the market. With the added strain of inflation, coeliacs may not have the money to spend an extra five dollars a week.

POTENTIAL IMPACT

Myocardial ischemia is a high-risk disease occurring in middle-aged and senior individuals when blood flow to the heart is obstructed by a partial or complete blockage of an artery by built up fats. After thrombolytic therapy, the heart tissue can be ruptured further called myocardial ischemia-reperfusion injury (MIRI). Treatments and medicines are scarce, however traditional Chinese medicine (TCM) have been used to treat patients with cardiovascular diseases. Saponins, the main active ingredient in TCMs, was discovered in a 2021 review by Frontier Pharmacology, that they can play a cardioprotective role via multiple mechanisms. They found that Chinese herbal medicine provides a broad application prospect for the development of highly effective and low-toxicity anti-MIRI drugs due to saponins in *Panax ginseng C. A. Mey.* (figure 8) having a strong regulatory effect on energy metabolism and saponins in *Aralia chinensis L.* have significant regulatory effects on calcium homeostasis (Wang, et al., 2021). So not only can they act as a gluten-alternative, saponins in TCMs can treat myocardial ischemia and MIRI.

Figure 8: Table of anti-MIRI effects of saponins in ginseng (Wang, et al., 2021).

Compound	Major plant source	Geographical distribution of plants	Dose/ concentration	Models	Mechanism
Ginseng total saponins	*Panax ginseng* C. A. Mey	Southwest China, East Asia and North America	100, 200 mg/kg, i.g.	Guinea pig MIRI model (*in vivo*) (Aravinthan et al., 2015)	Anti-oxidative and anti-inflammatory properties by reducing inflammatory cytokines and NF-kB
			50 mg/L for 60 min	Rat global MIRI model (*ex vivo*) (Wang et al., 2012)	Modulating TCA cycle protein expression to enhance cardiac energy metabolism; reducing oxidative stress
Panax notoginseng saponins	*Panax notoginseng* (Burk.) F. H. Chen	Southwest China	200, 500 μg/ml	Neonatal rat MIRI model (*in vitro*) (Wang et al., 2019)	Inhibiting oxidative stress via MiR-30c-5p
			30, 60 mg/kg, i.p.	Rat MIRI model (*in vivo*) (Liu X.-W. et al., 2019)	Regulating the HIF-1a/BNIP3 pathway of autophagy
			30, 60 mg/kg, i.g.; 0.05, 0.25, 2.25 mg/ml	Rat MIRI model (*in vivo*); H9c2 cardiomyocytes HR model (*in vitro*) (Chen et al., 2011)	Inhibiting apoptosis by activating PI3K/Akt pathway
Gypenoside	*Panax notoginseng* (Burk.) F. H. Chen; *Gynostemma pentaphyllum* (Thunb.) Mak	Southwest China; East Asia and Southeast Asia	50, 100, 200 mg/kg, i.g.; 5, 10, 20 μM	Rat MIRI model (*in vivo*); H9c2 cardiomyocytes HR model (*in vitro*) (Yu et al., 2016a; Yu et al., 2016b)	Inhibiting ER-stress and apoptosis via CHOP pathway and PI3K/Akt pathway; inhibiting NF-kB p65 activation via MAPK signaling pathway
			100 mg/kg, i.g. (*in vivo*); 10, 20 μM (*in vitro*)	Rat MIRI model (*in vivo*); H9c2 cardiomyocytes HR model (*in vitro*) (Chang et al., 2020)	Suppressing miR-143-3p level via the activation of AMPK/Foxo1 signaling pathway
Ginsenoside Rb1	*Panax ginseng* C. A. Mey.; *Panax notoginseng* (Burk.) F. H. Chen	Southwest China, East Asia and North America; Southwest China	40 mg/kg, i.g.	Rat MIRI model (*in vivo*) (Xia et al., 2011; Li et al., 2016)	Enhancing eNOS expression and NO content and inhibiting p38-MAPK signaling pathway
			20, 40, 80 mg/kg, i.g.; 1, 5, 10, 20 μM	Rat global MIRI model (*ex vivo*); rat MIRI model (*in vivo*) (Li C. Y. et al., 2020)	Activating mTOR signal pathway
			2.5, 5, 7.5 mg/kg, i.g.	Rat MIRI model (*in vivo*) (Cui et al., 2017)	Regulating energy metabolism by RhoA signaling pathway
Ginsenoside Rb3	*Panax ginseng* C. A. Mey.; *Panax notoginseng* (Burk.) F. H. Chen	Southwest China, East Asia and North America; Southwest China	2, 5 μM	H9c2 cardiomyocytes HR model (*in vitro*) (Ma et al., 2014)	Inhibiting JNK-mediated NF-kB activation
			5, 10, 20 mg/kg, i.g.	Rat MIRI model (*in vivo*) (Shi et al., 2011; Liu et al., 2013)	Anti-oxidantive, anti-apoptotic and anti-inflammatory activity; improving microcirculatory
Ginsenoside Rd	*Panax ginseng* C. A. Mey.; *Panax notoginseng* (Burk.) F. H. Chen	Southwest China, East Asia and North America; Southwest China	50 mg/kg, i.p.	Rat MIRI model (*in vivo*) (Zeng et al., 2015)	Activating Nrf2/HO-1 signaling pathway
			50 mg/kg, i.p.; 10 μM	Rat MIRI model (*in vivo*); neonatal rat myocardial cells HR model (*in vitro*) (Wang et al., 2013)	Activating Akt/GSK-3β signaling pathway and inhibiting mitochondria-dependent apoptotic pathway

CONCLUSION

In conclusion, saponins as a gluten-alternative can imitate the taste and texture of gluten containing foods that could aid in healing metabolic disorders and widen food horizons. However, there is still research into the right amount of saponins for the health benefits and avoid the health risks. Furthermore, because of the current cost of living crisis, some celiac disease sufferers are unable to afford the expense of saponin-made products, such as bread, if the price is like that of quinoa or other foods that are also gluten alternatives. Overall, with further research and development, saponins will become the most suitable alternative to gluten.

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