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Flatulence Caused by Soya and Its Control through Processing

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ABSTRACT

Elimination of flatulence is a challenging practical problem associated with the comsumption of soybeans as well as other food legumes and other selected foodstuffs. The problem is compounded by the variability in susceptibility among individuals. Research has established that the oligosaccharides–verbascose, stachyose, and raffinose–are the major cause of soybean flatulence. They escape digestion and are fermented by intestinal microflora to form excessive amounts of carbon dioxide and hydrogen. Hot water treatment, aqueous alcohol extraction, and isoelectric protein precipitation processes have been adapted to produce flatus-free products commercially. At the household level, soaking combined with germination appears to be a practical means of producing soybean sprouts having low flatus activity. Food legumes, which include some oilseeds, peas, and beans, as well as selected vegetables, contain enough of the oligosaccharides–verbascose, stachyose, raffinose–to be a major cause of flatulence in humans and animals. In the absence of alpha-galactosidases in the mammalian intestinal mucosa, these oligosaccharides escape digestion and are not absorbed. As a consequence, the active microflora in the ileum, colon, and fecal matter of the large intestine ferment them to form excessive levels of rectal gas, primarily carbon dioxide and hydrogen. In some instances, undigested starch and other carbohydrates contribute to the flatulent effect of diets. With 70% of the world's population being lactase-deficient (hypolactasia), susceptibility to flatulence would be more widespread with diets containing both food legumes and milk products.

Use of food additives, antibiotics, and phenolic compounds to inhibit flatulence is not a practical approach. However, soya processing technology used to manufacture protein concentrates and isolates can be adapted to produce flatus-free products from other food legumes. Hot water treatment, aqueous alcohol extraction, or isoelectric protein precipitation insolubilizes most of the protein and removes the oligosaccharides. Tempeh and tofu are two other soya products that exhibit little or no flatus activity. Soaking, fermentation, enzymatic hydrolysis, and germination can also be used to eliminate oligosaccharides. Tests with humans and rats indicate that a combination of such processes can be used to reduce flatus activity. The beneficial effects of germination on flatulence, often conflicting and contradictory, have been attributed to failure to control conditions that ensure removal of most of the oligosaccharides. Whether the high-molecular-weight soybean polysaccharides (dietary fiber), which normally do not cause flatulence, can be modified during germination to become substrates for flatus production by the intestinal microflora is not known. Such an effect could compensate for the loss of stachyose and raffinose.

INTRODUCTION

Food legumes, which include some oilseeds, peas and beans, are important sources of protein and calories for a large segment of the world's population. Elimination of flatulence associated with the consumption of such foods is a challenging scientific problem and is one of the research priorities recommended by the Protein Advisory Group of the United Nations, now referred to as the Protein Calorie Advisory Group (1). Requests for information attest to the continuing concern of many individuals for simple and practical solutions to the problem of gas production. Although there are many causes for the formation of gastrointestinal gas, consumption of certain foods accounts for most of the nonspecific gastrointestinal symptoms associated with flatulence. Abdominal pain, nausea, cramps, diarrhea, increased peristalsis, borborygmus and social discomfort may accompany the ejection of rectal gas. Several reports, after eliminating intestinal malabsorption problems associated with disease, indicate that intestinal microflora interact with certain carbohydrates in flatulent foods to produce gas, primarily carbon dioxide and hydrogen, with lesser amounts of methane. Raffinose, stachyose and verbascose cause flatulence in man and animals (2-4). Lactose is a major factor contributing to flatulence in a person with lactase deficiency.

In this report, the emphasis will be on soybean flatulence and on processing technology that can be used to prepare flatulence-free soya products. The role of the intestinal microflora and interactions between soybeans and other foods also will be described.

Oligosaccharides–Structure

Soybeans contain high levels of stachyose and raffinose and trace amounts of verbascose, whereas most other food legumes contain verbascose in the greatest amount. Many other foods also contain these oligosaccharides, which are related by having one or more α-D-galactopyranosyl moieties in their structure where the α-galactose units are bound to the glucose moiety of sucrose (glucose-fructose). Lactose, the disaccharide associated with flatulence in lactase-deficient individuals, is glucose-4-β-galactoside.

Oligosaccharides—Metabolism in the Intestinal Mucosa

Alpha-galactosidase. When alpha-galactosidase (E.C. 3.2.1.22 α-D-galactoside galactohydrolase) is absent in the intestinal mucosa of humans (5, 6), rats, and pigs (6), then raffinose, stachyose and verbascose remain intact and enter the lower intestinal tract. There they can be metabolized by the microflora to form large amounts of carbon dioxide and hydrogen. Less than 1% of administered high doses of oligosaccharide is able to get across the brush border membranes in the intestinal mucosa and enter the blood stream (7-9). Thus, since peristalsis increases, large amounts of substrate become available for fermentation in the lower intestinal tract.

Gitzelmann and Auricchio (5) showed that galactosemic children, who are unable to digest galactose, can use soya milk as a substitute for human and cow's milk and other galactose-containing foods. Galactosemia is an inborn error of metabolism caused by an inherited deficiency of galactose-1-p-uridyltransferase, which is one of the enzymes that catalyzes the conversion of galactose to glucose. Marked disease symptoms arise when galactose is absorbed into the blood (10).

Lactase. More than 70% of the world's adult population is deficient in lactase, a saccharidase found only in the small intestinal mucosa (Table I). Lactase activity decreases about 90% during early childhood, often before the age of 5 or 6 years. Changes in activity are genetically programmed and are not controlled by the amount of lactose in the diet. Prevalence of lactase deficiency (hypolactasia) ranges from 1 or 2% in Scandinavians to about 99% in Orientals. Lactase deficiency should be differentiated from lactose malabsorption caused by gastrointestinal diseases. The most accurate indirect test for lactase deficiency is breath hydrogen analysis, because the level of hydrogen is a direct reflection of microbial fermentation in the colon following a defined load of lactose consumed. Lactose tolerance or intolerance refers to response to the defined lactose load.

In Peru, 50% of the population become lactose-intolerant by 3 years of age, whereas in the United States, 40% of the black population become intolerant by 10 years of age in contrast to only 15% of the U.S. whites (11). The accelerated onset of lactase deficiency in developing countries may reflect the poor nutrition of the population in early childhood. Human studies in lactose-intolerant populations for the most part fail to demonstrate a clear induction of lactase activity through continuous milk consumption (11). As a consequence, those people should be doubly susceptible to flatulence from diets containing food legumes and dairy products.

TABLE I

Incidence of Lactase Deficiency[a]

Group	Lactase deficiency, % of population
White	
Scandinavian	3
North American	5-20
Black	
American	70
African	50
Other groups[b]	
Chinese	80-100
Indian	55
Filipino	95
Israeli	60

[a]Compiled from many sources; about 70% of world's adult population is lactose intolerant.

[b]Includes Asians, South American and most other population groups.

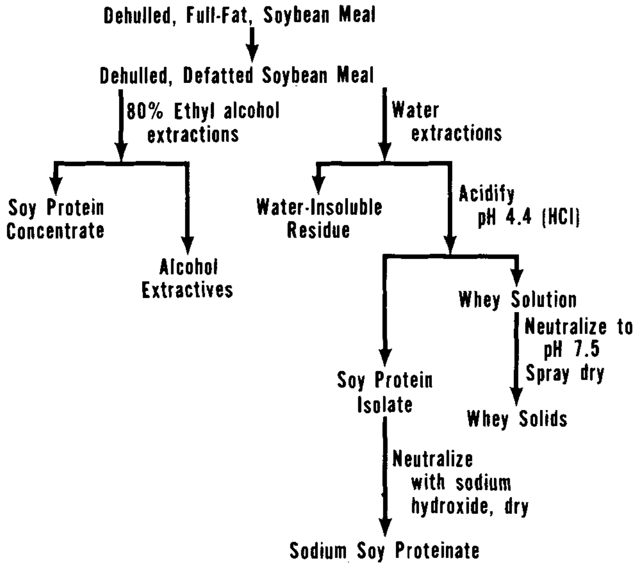

Fig. 1. Preparation of soya protein products for flatulence testing program with adult male subjects.

FLATUS ACTIVITY OF SOYA PRODUCTS

Human Tests

When a person experiences flatulence following a meal containing cooked dry beans, there is a sudden increase in volume of flatus that usually reaches a maximum in 4-5 hr, whereas with a meal containing soya flour, the flatus peak occurs in 8-10 hr. The predominant gases in all flatulent diets are carbon dioxide and hydrogen. Increased levels of nitrogen in rectal gas reflect swallowed air and do not signify flatulence.

Soya products. Four male graduate students volunteered to determine flatus activity of various commercially manufactured, toasted soya protein products (12). Each test lasted 6 days, during which the subjects consumed at each meal a measured amount of soya product prepared as shown in Figure 1. The diet was supplemented with specific amounts of hamburger, skim milk, fruits, cereal products and vitamin supplements; the diet amounted to about 2,400 calories. For comparative purposes, toasted (live steam treatment at 100 C for 40 min) navy bean flour replaced toasted soya flour in some tests. Results are summarized in Table II.

The gas-producing factor resided mainly in two products—80% ethanol extractives and whey solids. Both products contained about 55% carbohydrate, primarily as sucrose, raffinose and stachyose. Glucosides of sapogenins, sterols and isoflavones together with a wide range of consituents with low molecular weights were present in much smaller amounts.

In contrast, soya protein concentrate (72% protein and 25% polysaccharide) and the water-insoluble residue (25% protein and 75% polysaccharide) had very low flatus activity. Soya isolate (95% protein and $< 1.0\%$ oligosaccharide) was devoid of flatus activity. The polysaccharides account for most of the indigestible residue (dietary fiber) in soybeans (13). Raffinose, stachyose and the polysaccharides are not metabolized by mammalian enzymes, but only the oligosaccharides were utilized for flatus activity by the intestinal microflora.

The basal diet produced on the average 13 ml flatus/hr. In a navy bean diet, flatus volume increased to about 179 ml/hr.

Anaerobic microbial cultures that were isolated from dog colon metabolized raffinose and stachyose to produce

TABLE II

Effects of Soy Products on Flatus in Man (12)

Product[a]	Carbohydrate content (%)	Daily intake (%)	Flatus volume (cc/hr) Average	Range
Dehulled full-fat soya flour	27	146	30	0–75
Dehulled defatted soya flour	33	146	71	0–290
Soya protein concentrate	25	146	36	0–98
Soya proteinate	<1	146	2	0–20
Water-insoluble residue[b]	75	146	13	0–30
Whey solids[c]	56	48	300[d]	---
80% ethanol extractives[c]	55	27	240	220–260
Navy bean meal		146	179	5–465
Basal diet		146	13	0–28
Soybean hulls[e]		20	10	0–30

[a] All products were toasted with live steam at 100 C for 40 min (see Fig. 1 for details.)
[b] Fed at a level three times higher than that present in the defatted soya flour diet.
[c] Amount equal to that present in 146 g of defatted soy flour.
[d] One subject, otherwise four subjects per test.
[e] Unpublished data.

TABLE III

Relationship between Raffinose Plus Stachyose Content in Diet and Flatus Production in Man (18)

Type of diet	Oligosaccharide content (g) Raffinose	Stachyose	Total[a]	Flatus volume ml/8 hr	% Increase[b]
Defatted soya meal (50% protein)	0.86	4.16	5.02	800	205
Soya concentrate (60% protein)	0.36	2.46	2.82	590	51
Soya concentrate (70% protein)	0.14	1.34	1.48	524	34
Control diet (meat-fish)	---	---	---	390	---

[a] Amount supplied by 75 g (dry-basis) of each soy product.
[b] Percentage increase above control diet.

large amounts of gas. There was good agreement between in vitro tests and human studies, since the same soya products that cause flatulence in humans also had the greatest flatus activity in incubation mixtures of anaerobic cultures taken from the dog's ileum and colon mucosa (14). Measurement of hydrogen production in the rat also has potential for a predictive bioassay for flatulence in man (15).

Raffinose diets. Raffinose, when added to a soya isolate diet (which normally had a low flatus rate) at a level equivalent to the total amount of raffinose plus stachyose in a soya grit diet, produced just as much flatus as the soya grit control diet. Sucrose consumed at a level twice that found in soy grits did not cause flatulence. Most likely, stachyose in the diet would have produced even more flatus than raffinose, since Cristofaro et al. (2) found that stachyose and verbascose exhibited the highest flatus activity in rat experiments. During a 30-day study with six women aged 65–73 years, intestinal hydrogen production increased markedly as a result of fermentation of raffinose and wheat bran by enteric flora (17). Wheat bran contains appreciable amounts of oligosaccharides. Cereals contain at least two types of fermentable nondigestible components (17).

Twelve student members of a rowing team were given 75 g (dry-basis) of defatted soybean meal and two refined soya concentrates after their daily training (18). The extent of intestinal gas production after a soya meal containing 1.48–5.02 g of raffinose plus stachyose in comparison to a control diet of fish and meat is shown in Table III. Egested flatus was collected every 2 hr (2–10 hr) after each meal. Most subjects hardly noticed the release of 400 ml flatus over the 10-hr period. Even with a dietary intake of 1.48 g oligosaccharide, the most refined soya protein concentrate diet produced 35% more flatus than that produced with the control diet. A linear relationship existed between soy oligosaccharide content and flatulence in these studies.

Comparisons of soybean-food legume-lactose intolerance. As indicated in Table II, depending upon the subject and diet, flatus volume ranged from 0–465 ml/hr. Since the range of tolerance is extremely wide, it is difficult to establish the level of consumption of soybeans that would not cause flatulence in the general population. Unsubstantiated anecdotal information seems to show that more than 50 g defatted soya flour consumed in a single meal would significantly increase flatus volume. An intake of 100 and 200 g soybeans increased flatus volume about 2.5 and 3.5 times, respectively, above that recorded for a basal diet (19).

The intake of different legume foods/person/day for 63 countries (20) ranged from 13 g in 34 countries to 35 g in 25 countries to 57 g in 4 countries. These consumption ceilings are lower than those for cereals or meat. Soybean consumption as a food legume is relatively low in these countries. There may be a physiological limitation to the amount of food legume consumed. Whether this limitation is related to gastrointestinal disorders, allergic reactions or other causes has not been elucidated. Although flatus activity varies among the food legumes, based on the relative ability of navy beans and soybeans to produce gas (Table II), an intake of 35–57 g of certain legumes per day would be expected to be highly flatulent in some people.

Most studies suggest that many persons with lactase deficiency are intolerant to a physiologic load of 24 g of lactose, which is equivalent to two 8-oz glasses of cow's milk, even if taken with a meal to delay stomach emptying time. In the same subjects used to obtain the data summarized in Table II (unpublished data), consumption of one to two 8-oz cans of soya milk (based on defatted soya flour) produced 2–3 times more flatus than an equivalent amount of soya flour consumed in the form of cooked corn meal mush or biscuits.

Because of the high prevalence of lactase deficiency, particularly among people in developing countries, as well as differing intolerance to soybeans and other food legumes, it would be difficult to predict whether consumption of mixtures of milk products, soybeans and other food legumes in the same meal would create an intolerable flatulent response compared to individual consumption of the three protein foods at different times of the day. Such tests are needed to define practical approaches to controlling flatulence in a wide segment of the population. Synergistic stimulation of flatulence would not be surprising, since the gastrointestinal environment most likely would promote increases in bacterial populations to metabolize a wider variety of carbohydrates at a faster rate.

In some countries, soya concentrates, tempeh, tofu, fermented soya milk and possibly germinated soybeans could be substituted for whole soybeans, soya flours, and other legumes to prepare foods low in flatulence.

Other human tests. Steggerda (21) summarized a series of experiments demonstrating that antibiotics can inhibit the flatus activity of pork and beans. Similarly, plant phenolic compounds are effective flatus inhibitors in vitro and in intestinal segments of dogs because they inhibit the growth of anaerobic bacteria (14). Such treatments, however, are impractical.

In future studies on human flatulence, screening food mixtures by determining volume of expired air could prove useful in evaluating flatus activity and the effects of normal daily activity and emotional state of the subject on flatulence (22). Breath hydrogen analyses have shown that poorly digested cooked potato starch greatly increases flatus production in contrast with uncooked, but digestible, wheat starch when compared to a formula diet (22).

PRACTICAL CONSIDERATIONS FOR PREVENTION OR ELIMINATION OF FLATULENCE

A monograph on gastrointestinal gas reveals many facets associated with flatulence in humans; of particular importance is the role of the intestinal microflora (23). In vivo and in vitro studies demonstrate that *Clostridia* and other anaerobic bacterial types influence volume and composition of flatus (14, 21–24).

With billions of anaerobic and aerobic bacteria in the large intestine, the use of food additives and antibiotics (21) and phenolic compounds (14) to inhibit flatus activity of foods would not appear to be a practical approach, except perhaps in very susceptible subjects, since the number and type of bacteria residing in the ileum, colon and feces will vary considerably among individuals. Differing rates of passage of digesta down the intestinal tract, depending upon physiological and emotional factors, further complicate the situation. Therefore, the remaining approach is to develop procedures to eliminate the offending flatus factors.

Extraction of Oligosaccharides

Processing techniques used in the commercial manufacture of soya concentrates and isolates are employed to produce flatus-free soya products (25). For example, hot water treatment and aqueous alcohol extraction, which insolubilize most of the protein in soybean meal, can be used to prepare soya concentrates with low residual flatus activity. Soy protein isolates are devoid of flatus activity. Similarly, tempeh, a fermented soya product (25), has little flatus activity (17) because the soaking and cooking treatments and subsequent fermentation remove most of the oligosaccharides. Tofu (25), a protein-oil emulsion product prepared by treating hot water extracts of ground soybeans with calcium salts, is essentially devoid of flatus activity (19). Application of similar processes to other flatulent food legumes can be equally effective, provided starch is adequately gelatinized to assure maximum digestibility.

Enzymatic hydrolysis of oligosaccharides. As shown in Fig. 2, gas production is related to the degree that oligosaccharides and their corresponding intermediate hydrolysis products are broken down to monosaccharides. Gas production parallels the formation of simple sugars. Enzymatic processes (26–30), some of which have been patented, have not been used. Limited tests have shown that some of the products

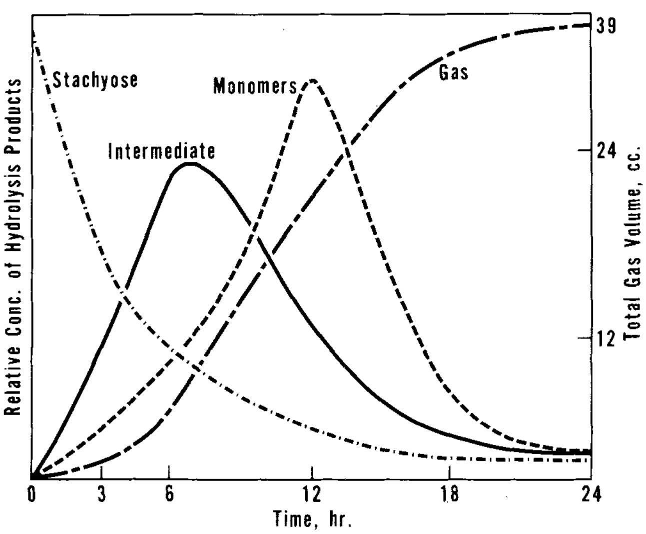

Fig. 2. Relationship between enzymatic hydrolysis of stachyose and gas production. Incubation with anaerobic culture isolated from the dog colon (14).

exhibited relatively high flatus activity and low flavor acceptability (19). Browning reaction problems are created, since toasting by live steam treatment is required to inactivate the enzymes and to eliminate the antinutritional factors in soybeans that inhibit growth and cause pancreatic hypertrophy.

An immobilized α-galactosidase continuous-flow reactor has been used to reduce raffinose content in beet sugar molasses (31). Hollow-fiber reactors for removing soybean oligosaccharides have been described; in these processes, soya milk is circulated around hollow fibers containing the immobilized enzyme. The oligosaccharides diffuse into the fiber, whereas proteins are too large to enter (32–35).

With such technology, it is possible to minimize the formation of objectionable flavors resulting from protein degradation by the presence of proteinases in purified α-galactosidase preparations. Immobilized enzyme processes have been adapted for many food applications, including the preparation of lactose-hydrolyzed cow's milk. There appears to be little commercial incentive, however, to develop flatus-free soya beverages with such technology.

Should cow's milk production decrease appreciably, lactic acid fermentation of soya extracts may be promising, because lactic acid bacteria readily hydrolyze soybean oligosaccharides (36). Acid milk beverages, yogurt, and many fermented drinks and foods prepared from a variety of foodstuffs are used worldwide (37, 38). Wang et al. (39) examined several strains of *Lactobacillus* for their ability to ferment soya milk; they found that soya milk fermented by *L. acidophilus* NRRL B–1910 had an acceptable flavor. In addition, the objectionable grassy-beany flavor usually associated with soya products was eliminated, as judged by a trained taste panel. Yogurt prepared from soybeans by a mixed culture of *L. acidophilus* reportedly has an acceptable flavor score (40).

And yet, in spite of the demonstrated ability of lactic acid bacteria to hydrolyze the oligosaccharides in soybeans and in cow's milk, there is no assurance that flatus activity will in fact be eliminated in commercial products (41). For example, ingestion of one quart of homogenized cow's milk with *L. acidophilus* culture resulted in 76 passages of gas per 24 hr by an excessively flatulent patient (41). On the other hand, when the patient drank one quart of milk incubated with one or two packets of a commercial source of lactase (0.7 g lactase/packet), gas excretion for 24 or 48 hr averaged only about 26 times per day when taken along with a normoflatulent diet that usually resulted in about 19 passages per day.

The low flatulent diet described in this paper, as derived empirically by flatugraphic recordings, proved highly effective when given to three other patients with excessive flatulence for two of the flatulent subjects and ineffective for the third one.

Dhokla and Idli are fermented food products prepared from a batter of cereals and dehusked, split legumes (dal). Comparable products, soya-Dhokla and Soyaidli, made from soybeans in place of the usual legume, are effective in feeding children suffering from kwashiorkor. The large number of microorganisms involved in the fermentation process result in large increases in vitamins and free sugars (38). Whether flatus activity decreased concomitantly under such conditions was not determined.

Germinating Soybeans

Literature reports reveal that germinated soybeans may have great value as a human food because the protein quality of cooked soybean sprouts is comparable to that of toasted full-fat or defatted soya flour (42). In some parts of the world, germinated soybeans could be of added nutritional benefit because of the amounts of ascorbic acid and β-carotene present in them, whereas mature soybeans are practically devoid of these vitamins (42). Reports indicate that germinated soya flour, by replacing 10% wheat flour, slightly outperformed a commercial dehulled defatted soya flour used in breadmaking and received higher acceptability scores by a taste panel (43–45). Incorporation of properly germinated wheat and soybeans into bread could be a practical means to prepare highly nutritious, low cost flatulent-free foods.

The beneficial effects of germination on the protein quality of soybean and other legumes are conflicting and often contradictory. The same situation exists with flatulence. Becker et al. (46) observed that the reduction in stachyose and raffinose during autolysis of California white beans reduced flatulence, as measured by hydrogen production in the rat. Other researchers (19) did not observe any reduction in flatus activity of germinated white beans, other beans and soybeans when fed to humans. In later studies (19, 47, 48), the oligosaccharide content was not determined. Although few conclusions can be drawn from the many studies that have been made, it may be deduced from these divergent results that, depending on the type of food legume and the conditions of germination, glycosidase activity, and particularly, α-galctosidase activity, may vary widely and thereby affect flatus activity of germinating beans. High-molecular-weight polysaccharides (insoluble residue fraction, Table II) normally are devoid of flatus activity. Possibly, these polysaccharides are partially hydrolyzed during germination, making them susceptible to further metabolic breakdown by intestinal microflora, producing flatus and thereby compensating for the loss of oligosaccharides. The failure to reduce flatulence in other germinated legumes also could be attributed to conditions that allow for greater amounts of starch to escape digestion and thus to become available for flatus production by intestinal bacteria. More studies on the comparative availability of carbohydrates as they are modified in the intestinal tract may provide the needed information (47, 48).

Germination process. Germination actually involves a combination of various treatments that includes: soaking, leaching, pH and temperature adjustments, and cooking after germination. All of these treatments together with the initial viability of seeds can affect extractability and enzymatic hydrolysis of the oligosaccharides.

Under the conditions employed, soaking whole soybeans for 15 hr at room temperature was ineffective in reducing oligosaccharide content (Table IV). Up to 60% of the oligosaccharides can be removed by boiling for 60 min both with and without sodium bicarbonate; percentages of protein loss were small.

Upon germination, which actually begins during the soaking phase, seeds undergo marked metabolic changes, and reserve carbohydrates become susceptible to breakdown. According to East et al. (51), the oligosaccharides disappear after 3 days of germination, whereas Adjei-Twum et al. (52) reported 4 days are required to essentially hydrolyze most of the oligosaccharides; Hsu et al. (53) reported similar results. Kim et al. (49) indicated that oligosaccharides in soybeans decreased 70% in a 4-day germination test.

How much of a reduction in oligosaccharides during germination is needed to significantly reduce the flatulent effect of soybeans and other food legumes has not been precisely determined. However, low flatus activity was observed in rats fed germinated black gram beans (87% reduction in oligosaccharide content) at 50% of the diet (54). The reason germinated white beans, other beans and soybeans had varying effects on reducing flatus activity was not readily apparent because oligosaccharide content of the

TABLE IV

Protein Loss and Oligosaccharide Removal from Whole Soybeans by Various Treatments

Treatment	Bean-to-water ratio	Protein loss (%)[a]	Removal oligosaccharide (%)[b]
Soak, rt, 15 hr	---	---	8[c]
Boil, 20 min, water	1:10	1.0	33[d]
Boil, 60 min, water	1:10	2.6	59[d]
Boil, 20 min, 0.5% $NaHCO_3$	1:10	1.3	21[d]
Boil, 60 min, 0.5% $NaHCO_3$	1:10	6.8	60[d]
Boil, 60 min, pH 4.3	1:10	2.0	46[d]

[a]Protein/100 g protein in original dry bean.

[b]Oligosaccharide/100 g oligosaccharide in original dry bean.

[c]Kim et al. (49).

[d]Ku et al. (50).

germinated products was not determined (19, 55).

The divergent results reported for the effect of germination on flatus activity in soybeans may indicate that the high-molecular-weight polysaccharides, which normally do not cause flatulence (Table II), may have been partially hydrolyzed during germination. Therefore, they may have become susceptible to conversion into rectal gas by the intestinal microflora. The failure to eliminate flatus activity of other germinated food legumes may be related to the presence of higher than normal levels of undigested starch. Flatulence problems associated with other food legumes have been reviewed (56).

CASE HISTORIES

Whenever accounts of flatulence research get reported in the popular press, we receive testimonials within 1–2 weeks with an anecdotal discussion of how the flatulence effect can be completely eliminated. Most of them appear to be subjective conclusions in the absence of analytical data. Some of the more common remedies include: (a) addition of one teaspoon of baking soda to "release the gas," addition of one ounce of castor oil per pound of beans, or addition of special herbs and spices, etc. (whether the cooking water is discarded is seldom mentioned); (b) hybridization of a cross between Boston navy and Mexican pinto beans; and (c) development of local unspecified soybean varieties. Elimination of soya oligosaccharides by genetic means, however, does not look promising (57).

Case Study of an Excessively Flatulent Person

Since most anecdotal reports must be discounted because of the lack of controls, the story of a 30-year-old male who had a 7-year history of passing excessive flatus is extremely valuable (58). Over a 2-year period, the subject developed a flatugraphic recording technique to record the exact time of each belch and passage of gas (at least 7 ml of rectal gas). All foods consumed were also measured.

During this period, the subject's gas evolution averaged 34 ± 7 times per day compared to a normal age-matched control of 14 ± 4 times per day (41). Flatus composition was 70–80% carbon dioxide and hydrogen, which reflected that a true case of microbial fermentation as the cause of flatulence. The subject was not an air swallower since nitrogen content of the flatus was low; he was lactose-intolerant, since 800 ml of gas/4 hr was excreted following consumption of two glasses of milk, compared to less than 100 ml by normal controls.

Over 130 different foods were tested. The basic test diet, previously reported to have minimal flatus activity, included tuna, eggs, peanut butter, lettuce, broccoli, orange juice, corn chips, and berries; these foods were eaten at breakfast. At lunch the various 130 test foods were eaten at a level three times the amount normally eaten at a meal. Dinner consisted of normoflatulent foods. Gas passages/24 hr were recorded in the 24-hr period from lunch to lunch. Flatulence classification of the foods is summarized in Table V. Based on these results, a low flatulent diet would call for restricted intake of dairy products, certain wheat products, legumes, and selected fruits and vegetables. The practical significance of a so-called normoflatulent diet (Table V) for general application to a particular segment of the population needs further study.

When three other flatulent patients were switched from a regular diet to a diet containing foods with low flatulence potential (Table V), average gas passages of 26-29 per day were reduced to 9–11 passages per day, whereas the third patient showed no significant improvement. Most certainly, however, minimal flatulence would occur when specific carbohydrates, that is those which are utilized by ileal, colonic and fecal bacteria to produce gas (59), are excluded from the diet.

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TABLE V

Flatulence Index of 130 Different Foods (41)[a]

Normoflatugenic, up to 19 passages of gas per day[b]	Moderately flatugenic, 20–40 passages per day	Extremely flatugenic, 40 or more passages per day
Protein–meat, fish, fowl	---	Milk and milk products,[c] beans
Vegetables–lettuce, cucumber, broccoli, peppers, avocado, cauliflower, tomato, asparagus, zucchini, okra, olives	Potatoes, eggplant	Onions, celery, carrots, brussels sprouts
Fruits–cantaloupe, grapes, berries	Citrus fruits, apples	Raisins, bananas, apricots, prune juice
Carbohydrates–rice, corn chips, potato chips, popcorn, graham crackers	Bread, pastries	Pretzels, bagels, wheat germ
All nuts	---	---
Miscellaneous–eggs, nonmilk chocolate, jello	---	---

[a]Individual foods ingested at the lunch hour at a level three times the amount normally eaten at a meal.

[b]Gas passages of less than 7 ml not counted.

[c]One quart *L. acidophilus* cultured milk, 76 passages of gas/24 hr; one quart lactase-treated milk, 26 passages of gas/24 hr.

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