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## Can Drinks Alone Supplement Nutrition?



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### ABSTRACT

Food is a catchall term usually used to describe both solid and liquid nutritional intake, with each thought to fill different roles and supply different nutrients at each meal. It is common to need both liquids and solids; however, more recent trends have seen an increase in the number of single solution liquids, called complete meals, which are supposed to provide all of the necessary nutrients in a single format. This raises a question as to whether it is necessary to ingest both solid and liquid foods to remain healthy. Here, we focused on evaluating liquid foods (so-called drinks and beverages) and examined whether it is possible to meet all of the nutritional requirements for each meal using only a liquid format.

## INTRODUCTION

Foods are primarily made up of solids and liquids. There are also intermediate semi-solid smoothies and jellies, liquid foods for the treatment of diseases, and soups, such as miso soup, which may be mixed with solids. Various foods can be roughly divided into solids or liquids depending on whether they need to be chewed with teeth or they can be swallowed as they are. Conventional wisdom suggests that these foods should be balanced, as each is associated with different roles and nutrients. Liquid foods can rapidly transfer nutrients (mainly water and sugar) directly to the digestive tract, often helping to smoothen the movement of solid foods from the oral cavity to the esophagus (especially substances that are low in water). In other words, it is common to ingest both liquids and solids in the same meal. Japanese culture suggests that an ideal meal should comprise one soup (liquid food), three side dishes (solid food), and rice, which acts as the core staple in the region. This type of meal is traditionally referred to as “*IchijuSansai* (1 soup and 3 side dishes, in Japanese).” However, recent advances in so-called “complete meal” liquids have seen these options gain a significant amount of popularity<sup>1,2)</sup>, raising some questions about whether both solids and liquids are still required for a balanced diet.

Here, we focused on liquid foods (so-called drinks and beverages) and examined whether it is possible to gain all of the nutrients needed from the ingestion of these complete meal solutions. We also evaluated the pros and cons of these solutions and explained why we do not believe that complete meal solutions are the final remedy to nutritional requirements. However, we have primarily focused on foods that can be swallowed without chewing, regardless of their nutritional value. We also evaluated various semi-solid foods, as discussed above, and included any of those that do not need to be chewed and can be swallowed quickly even if there is a solid component to these foods.

### *Characteristics of liquid foods*

Here we describe the defining characteristics of liquid foods and compare these with the characteristics of solid foods. Many of the findings presented here discuss the differences in the effects of liquid and solid foods and not the impact of the food itself. For example, many of the advantages of liquid foods are the disadvantages of solid foods.

Liquid foods such as water and tea can be easily ingested while being physically active or commuting to and from various activities. One of the key features of liquids is that they can

be stored in convenient to carry containers such as water bottles and may be prepared in advance. In addition, there are a wide variety of ready-to-eat items available from various commercial outlets, such as vending machines, making them easy to obtain while on the go. Although, this is true of various solid foods as well. These solid foods include so-called dietary supplements and sweets such as chocolate bars and candies and in some circumstances may include various types of fast food. These may be ingested in as many places as liquids, unless otherwise restricted. In some cases, only liquids are allowed in public facilities such as libraries and transportation. This difference is thought to be due to the production of food debris and other waste materials which may contaminate surfaces. Places like libraries may also consider factors like dirty hands and damage to their goods.

Next, consider the difference when you put it in your mouth. Solid foods must be chewed while liquid food can be poured directly into the digestive tract. This can have a drastic impact on how long it takes to ingest certain types of foods, making liquid foods, which can be consumed faster, and more appealing under specific conditions, especially when time is a factor. This is part of the reason that liquids are more commonly consumed during physical activity, not only are they more easily ingested but they are also easier to digest. As a matter of course, liquid foods contain larger amounts of water helping consumers ingest enough water and keeping the body hydrated while making absorption easier. Hydration is critical for continued survival, with many studies sighting that you should ingest at least 2 L of water a day<sup>3)</sup>, and demonstrating that frequent fluid intake prevents heatstroke in the hotter weather, making beverages a critical part of everyone's diet. However, it is not good to take in too much water as this may result in water poisoning (systemic toxicity caused by excessive water intake, which results in hyponatremia, convulsions, and in severe cases, death)<sup>3)</sup>. There are also concerns around increasing rates of obesity resulting from the excessive intake of high-calorie beverages<sup>4,5)</sup>. It is difficult to consume vast amounts of solid food in a single sitting as this requires increased chewing. At first glance, this seems to be a disadvantage, but it is thought that it compensates for the disadvantage of excessive liquid consumption and might reduce obesity in some populations. When a person feels full, they stop eating; this feeling of fullness is controlled, in part, by increased levels of nutrients such as glucose in the blood, but this is not the only control mechanism. Chewing also stimulates the satiety center of the brain, which makes you feel full, reducing the amount of food consumed. In addition, chewing promotes saliva secretion and saliva contains a large number of digestive enzymes, which break the food down making it easier to absorb. This means that the metabolism is

already engaged before the food reaches the digestive tract helping the nutrients enter the bloodstream faster. Since the action of chewing does not occur when ingesting liquid food there is no reason to produce saliva. Even if it is ingested with solid food, liquid foods quickly move to the esophagus, making it difficult to evaluate metabolic reaction time<sup>6)</sup>.

After passing through the oral cavity, food passes through the esophagus and is metabolized by digestive juices, containing digestive enzymes, in the stomach and small intestine, allowing for the absorption of nutrients into the body. Liquids are less susceptible to enzymatic reactions, but they tend to be less complex, allowing for much faster absorption. This is because solid foods need to be broken down into smaller and smaller functional groups until reaching the macromolecule stage where they can be absorbed<sup>7)</sup>. This means that solid food releases the nutritional groups more slowly allowing a slower uptake and more prolonged energy release.

This is not found in liquids. This increased digestion time also eliminates the feeling of hunger. The nutritional value of solid foods such as vegetable changes depending on whether they are eaten raw or cooked, which is thought to be related to the disruption of the cellular membranes in these substances during cooking<sup>8,9)</sup>. This destruction can also be accomplished by chewing, but it is more difficult to complete this process through chewing alone. Some suggest that these destructive processes are also achieved when substances are made into liquids, as in a smoothie, with these processes serving to disrupt the cellular structure in much the same way as cooking and chewing. Also, some nutrients, including quercetin in onions and vitamin E in avocado<sup>8)</sup>, are decomposed during heating. Unless they are liquefied without heating<sup>9)</sup>. This suggests that liquids are a better source of immediate energy but solids are better in terms of sustained nutrient supply and satisfaction. However, it is worth noting that absorption rates also vary based on individual differences in both the mastication rate and the function of the GI tract. If the foods are not chewed well by the teeth, they reach the gastrointestinal tract in larger chunks increasing the digestion period and allows more nutrients to be lost as waste. This ratio is considerably higher in solid foods, and chewing is considered to vary from person to person. The energy values of certain foods are indicated on their packaging, but these values represent the amount of energy they can supply when under the influence of an average metabolism<sup>10)</sup>. This means that they often fail to consider individual and environmental differences. There are some reports that suggest that there are no critical differences between different morphologies<sup>11)</sup>, and that these values likely already

consider this differences<sup>12)</sup>. In summary, the absorption of nutrients from solid foods is characterized by slow digestion and absorption, prolonged residence (residence time) in the digestive tract, and low absorption rates in most of the GI tract<sup>6)</sup>. These factors can combine to produce poor digestion, which may contribute to the larger variation in the absorption ratios for solid foods.

### ***Easier and harder to take by drinks***

In general, it is harder to obtain proteins from liquid foods. The main reason for this is that only a few naturally liquid products (*e.g.*, fruit juice) contain protein. This is likely because proteins are not that soluble in water, reducing their contribution to the intracellular and extracellular fluids used to produce liquid foods. Milk and Soy-milk are typical examples of the small number of naturally protein-rich liquid foods. However, these liquids more closely resemble a solution of fine particles, as evidenced by their natural turbidity (therefore, milk is not strictly speaking a completely liquid form of sustenance). There are also several different kinds of artificial protein drinks. On the other hand, sugar dissolves easily in water but should be ingested with caution. Too much sugar is very bad for you; nevertheless, many beverages are very rich in sugar<sup>4)</sup>.

If a liquid contains a substance produced following the digestion of a larger molecule it is often easily absorbed in liquid format. Liquids pass quickly through the digestive tract and are therefore less susceptible to many metabolic reactions before absorption. This means that liquid nutrients should be present in their most basic format to allow for rapid uptake. One example of this is amino acids, which are normally produced following the digestion and decomposition of proteins but are now added to many beverages. In recent years, it has become clear that small peptides are also easily absorbed<sup>13)</sup>, making them an ideal addition to many energy drinks.

Also, many organic acids including citric acid, which are quickly absorbed and known to exert an immediate effect, are included in high concentrations in various beverages. Since these start as small molecules and are not poorly differentiated by digestion, they can be ingested in either solid or liquid format. This is also the case for other macromolecules like fatty acids, vitamins, and minerals. It should be noted that when people ingest multiple non-compatible foods, known in Japan as “eating each other”, there may be some interference reducing the digestive efficiency for all of the items involved often changing the absorption

rate for various components. For example, it is known that organic acids chelate several minerals increasing their absorption rate by neutralizing their charge. In some cases, such as tannin and iron, a precipitation reaction occurs, and absorption is reduced. This is not observed when mixing liquid foods, suggesting that this is a unique problem for solid food products. This is likely because it is rare to drink many kinds of beverages at the same time.

### *Other effects of liquid foods*

It is also important to consider the effect of liquid foods on other parts of normal life. Liquids are often ingested in combination with medicines, this means that it is important to evaluate any potential interfering effects of specific beverages. Since absorption rates change in response to the decomposition or dissolution of the active compounds, there may be some significant interaction between these compounds and any beverage ingested with their prodrug vehicle<sup>14</sup>). Normally, water (which does not contain organic substances such as nutrients) is used to control the absorption efficiency of drugs and the disintegration rate of tablets in medical studies, however, these may change when ingested with a different liquid. An overview of these effects is shown in Table 2. It is not advisable to take tablets without some liquid. Inflammation of the digestive tract, such as the esophagus and stomach, may occur, or absorption of the drug may be delayed, and the expected effect of the drug may not be obtained. There is almost no problem with substituting tea for water although some medicines such as iron agents, may not be as effective when ingested using tea due to some interference from the tannins. Taking medicines with carbonated drinks can change the pH of the stomach and increase or decrease the absorption of these medicines and the caffeine in coffee or tea may overlap with some of the ingredients in over-the-counter cold remedies. Caffeine overdoses may cause side effects such as headache, insomnia, and frequent urination. It should be noted that other drugs (such as xanthine-based drugs for asthma and benzodiazepine-based drugs for mental illness) cannot be taken in the presence of caffeine. Also, the calcium in milk may reduce the effectiveness of certain pharmaceutical compounds. For some antifungal and neuropsychiatric drugs, milk promotes the absorption of the drug, strengthening its action, and increasing the likelihood of side effects. Grapefruit juice has been shown to inhibit the action of some enzymes. Some medicines should be taken with water to make them easier to swallow, these include calcium channel blockers, insomnia drugs, immunosuppressants, antiplatelet drugs, and hyperlipidemia drugs used in hypertension and angina. Consuming alcoholic beverages (including ethanol) may have a

drastic effect on the activity of various medications and in some cases, it may counteract any positive effect of the drug compound completely. In other cases, combining alcohol and some medications, such as sleeping pills or antihistamines, can be dangerous as it can lead to a life-threatening coma. Medication should also not be combined with energy drinks as there is any number of unwanted side effects from combining these two items.

It is worth noting, that even though this is unlikely to be liquid food, it has been found that eating foods containing soybeans suppress natural increases in blood glucose levels<sup>15</sup>). This is a so-called low GI food (GI is an abbreviation for glycemic index, which indicates an increase in postprandial blood glucose level). Foods with low carbohydrate content, such as vegetables and indigestible components such as dietary fiber, are thought to limit the absorption of sugar into the body<sup>16</sup>). The same effect can be obtained when both liquid and solid food is supplemented with soybean-derived components, this is also known to be increased when used in a liquid format given the more rapid absorption of the soybean compounds.

Liquid diets are also often used during the convalescent period. In the case of cerebrovascular disorders such as cerebral infarction and cerebral hemorrhage, and nerve and muscle diseases, swallowing becomes difficult. For patients with these kinds of conditions chewing also becomes difficult limiting their ability to ingest solid foods, this means that extremely soft foods that require almost no chewing may be used as the primary source of nutrients. Liquid diets are used in the earliest stages of these diseases however when dysphagia occurs, patients experience an increase in nutrition deprivation, due to reduced food intake and pneumonia, resulting from the aspiration of food particles. If these symptoms become more severe and food cannot be ingested by mouth, nutrients may be supplied by intravenous drip, but it is preferable to retain the patient's quality of life (QOL) for as long as possible so moving to intravenous diets is usually a very last resort. To help retain these functions as long as possible, most patients are feed meals that are a mix of solids and liquids with the easiest to ingest foods being introduced first and more difficult food last to encourage chewing while ensuring sufficient nutritional uptake.

There is also a growing trend of adopting a liquid diet (mainly tea, water, enzyme liquids, etc.) to lose weight<sup>17</sup>). These diets rely on calorie restriction by ingesting low-calorie foods that do not contain additional nutrients. Studies suggest that this method is effective only for a short period of around 1-3 days<sup>18</sup>), and that this type of diet can be detrimental to your

health if applied for too long. It is dangerous to adopt this kind of diet for prolonged periods as you may become deficient in any number of proteins, minerals, or vitamins<sup>18)</sup>. It is recommended that patients only do this for very short periods while under the strict supervision of their physician. It is better to gradually reduce and increase calories, and introduce a step of acclimatizing to solid or semi-solid before and after the start. If you feel sick, you should consider ending your diet and seeking medical advice and one should be aware of rebounds<sup>17)</sup>. After a diet, you often eat too much food, and even if you eat the same amount of solid food as before, you may gain weight as you have restricted your metabolism and changed how your body functions.

You can also obtain “complete meal” liquids<sup>1,2)</sup>. A complete meal is any food that contains all of the energy and nutrients a person may need to function normally for a given period of time<sup>2)</sup>. Typical examples include milk and yogurt. One thing to keep in mind is that while many types of nutrients are included, the amount may not be sufficient for humans. If you try to get all of your nutrients from a single type of complete meal, you will often end up with an excess of other ingredients. Even if you eat a complete diet, it is not usually sufficient to maintain every nutrient at the appropriate level and most adults are forced to supplement their normal diet. Recent studies have focused on developing artificially defined complete meals with the exact nutrient composition needed to stay healthy<sup>1,2)</sup>. Although many of these have not been released in Japan. Typical examples include the powdered drink “Soylent” which is produced in Silicon Valley in the United States in 2014 and “COMP” developed in Japan. These artificial foods are perfectly balanced and designed to allow for the perfect proportion of every nutrient, however, the lack of chewing reduces overall satisfaction with these foods. If you want to be satisfied, you need to ingest these with water or drink them very slowly. In addition, the amounts of nutrients required per day vary from person to person and are determined by age, gender, and exercise. Since soy is a western food there is a risk it may contain more protein and fat than is required for the average Japanese citizen<sup>1)</sup>. These meal “replacements” cannot be fine-tuned to suit everyone suggesting that their broad application may still be some time away. In addition, meals also play an important role in a person’s mood and enjoyment of life. Nutritional gain is not the sole reason we eat food. This means that for those who are busy and want to eat quickly while maintaining a balanced diet these might be valuable additions to their kitchen. However, eating the same food all the time may result in some degree of depression so this should not be viewed as the sole source of nutrition and should be eaten as part of a normal balanced diet<sup>1)</sup>.



## CONCLUSION

Our analysis suggests that liquid foods alone are sufficient for nutrient supplementation. However, liquid meals are unlikely to satisfy or fulfill the more esoteric needs around food. Most people need to enjoy the appearance, smell, and taste of multiple dishes to feel satisfied. This means that it is important to include a variety of shapes and colors, including multiple solid foods into each meal, even if the liquid portion could provide all of the nutritional requirements on its own, satisfaction is only likely if all of these needs are met. It is also worth noting that chewing is a critical function and important for metabolic programming<sup>11)</sup>, suggesting that the intake of solid food has other functional implications and while you could be nutritionally sound on a liquid-only diet you would likely require some other supplementation in the absence of chewing. When we do not chew our jawbones and muscles become fragile and saliva production is reduced, which might impact speech. Taken together this suggests that chewing is a critical function and should be maintained.

Solid foods do not necessarily satisfy all our nutritional needs on their own. However, their taste, visual appeal, and varying texture all add to the overall enjoyment of the meal. While it is easier to get nutritional supplementation from liquid foods most data suggests that humans still need to ingest solids, even if they are not the primary source of nutrition. For this reason, we believe that both solid and liquid foods are still needed to maintain a healthy relationship with food.

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**Table No. 1: Differences between the liquid and solid foods discussed in this paper**

Contents	Solid food	Liquid food
How they are distinguished in this paper	Foods that need to be chewed. Foods that may be difficult to swallow.	Easy to swallow without chewing. Including soups with solid ingredients such as smoothies and miso soup
Easy to carry	Many of the things that are considered meals are not easy to carry. Some small packages such as sweets can be easily carried.	Easily carried and consumed from a specialized container, e.g., a PET or water bottle.
Easy to ingest	Often requires further processing such as chopping and heating. It takes time to digest and absorb even after chewing.	In many cases, it can be ingested without further cooking.
Behavior in the oral cavity	It is chewed in the mouth producing small lumps, and degradation is started by the digestive enzymes in saliva, partially reducing its molecular weight. A feeling of fullness is obtained by chewing.	It is not easily metabolized in the oral cavity and moves quickly to the esophagus. It is difficult to get a feeling of fullness until the nutrients are absorbed by the body.
Behavior in the gastrointestinal tract	Gastric juices and enzymes continue the digestion started in the oral cavity further reducing the molecular weight. The smaller ones are absorbed one after another from the small intestine, but they progress gradually.	Even in the digestive tract, residence time is shorter than that of solid foods, and there is not much change in these substances due to metabolism. It is quickly absorbed from the intestines.
After absorption	The absorption rate of nutrients from liquid foods is higher (in the case of substances that are originally small molecules and fine particles). After absorption these products are broken into the same component molecules and their metabolic behaviors are the same.	

Easily ingested nutrients	All nutrients (slightly lower in water).	Water and sugar (including other small compounds with high water solubility).
Nutrients that are difficult to ingest	Some additional water may be required to aid swallowing	Proteins are difficult to ingest. If you do not eat solid foods at the same time, you may run out of vitamins and minerals.
Unique characteristics of each food type	Excellent for prolonged nutrient uptake and release. Absorption rate is low and changes depending on chewing, <i>etc.</i> (There are several differences based on both physical condition and individual differences). Nutrient utilization rate changes based on ingestion, time of day and format.	Excellent for rapid absorption of low molecular weight nutrients for more immediate use in the body. Absorption rate is high and does not change much. Combined consumption is unusual.

In this paper, semi-solid foods such as jellies were also treated as liquid foods.

**Table No. 2: Summary of the types of medication affected following the ingestion of specific liquid foods**

Drinks	Typical examples of affected medicines
Water, plain hot water [Drink standards]	None
None	Not unlimited but considered to cover many medicines.
Green tea	Iron agent, <i>etc.</i>
Carbonated drinks	Medicines where the main component exhibits high degrees of acidity or alkalinity
Coffee, tea	Asthma medicines (xanthine compounds), mental illness medicines (benzodiazepine compounds), gastric ulcer medicine
Milk	Antifungal drugs, some neuropsychiatric drugs

Grapefruit juice	Calcium channel blockers, insomnia drugs, immunosuppressants, antiplatelet drugs, hyperlipidemia drugs, <i>etc.</i>
Liquor	Hypnotics, antihistamines
Nutritional Drinks	Not limited but considered to cover many medicines.
Aojiru(vegetable juice drink made from green leafy vegetables)	Warfarin

Based on the data in reference 13).

