Power Flour

(High Diastatic Milled Barley Malt)

Its Important and Critical Role in the Care of Weanling Infants and the Severely Malnourished

By

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Table of Contents

Power Flour
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Power Flour

Purpose

This paper is based on a literature review and its purpose is to document the basis for the use of PowerFlour in the care of human infants who lack the availability of breast milk and the treatment of malnourished children and adults in developing countries. How PowerFlour works, its safety, and its role in preventing and treating malnutrition and starvation in developing countries will be elucidated.

What Is PowerFlour

Milled high diastatic barley malt is a natural, inexpensive, food grade flour that contains naturally generated digestive enzymes. A small Rotary-based group has been distributing this malt as a food supplement to help in the care of weanling infants as well as children and adults suffering from malnutrition in 60 developing countries for the past twelve years. The group has named this high diastatic barley malt PowerFlour. When a small amount of PowerFlour is added to a hot starchy food or porridge, the diastase in the malted barley converts the mixture to a semi-liquid without adding extra water. The changes brought about by PowerFlour also increase the bioavailability of the calories (sugar) and nutrients (soluble proteins, free amino acids, and trace minerals) contained in the cereal grain for infants who don't have breast milk available for what ever reason and for malnourished people throughout the world.

Barley malt has been used for centuries for brewing beer, and high diastatic barley malt (PowerFlour) has also been used in the baking and confectionary businesses, thus demonstrating its long-term safety. Malted barley is included on the "Generally Accepted as Safe" (GRAS) list of the United States Food and Drug Administration (FDA) [1].

Brewer's malt diastase levels are 100 to 140 diastatic power (DP). The higher diastatic malts, including PowerFlour contain over 200 DP. Brewer's malt and its contained enzymes is the most studied. Findings from these studies show the impact of barley malt enzymes on cereal grains and are used to document the efficacy of PowerFlour. The major advantage of using high diastatic malt is that it breaks down carbohydrates at a faster rate than does brewer's malt due to its higher concentration of amylases [2].

Two hundred twenty seven million bushels of barley are produced annually in North America [3] and 0.5% (1.1 million bushels) is processed into high diastatic barley malt or PowerFlour at a cost of $13.00 for 50 lbs. This amount yields 24,000 (1.25ml) supplements for one-cup servings of porridge or starchy food meal. This means that for less than 1 ½ cents per week, a child or adult could receive 4 cups per day of nutritious, easily-consumed gruel. PowerFlour is not only safe, but it is also inexpensive.

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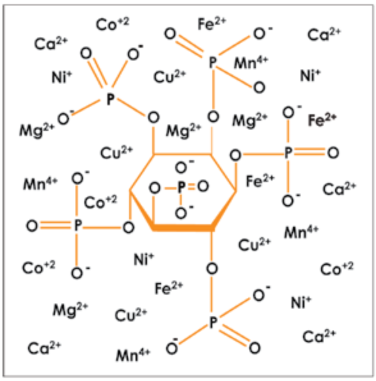
Enzymes

The significance of PowerFlour is not that it is flour or a food grade powder, but that it is a concentrated source of enzymes. The major enzymes that are present in PowerFlour are amylases (diastase), proteases, and phytases.

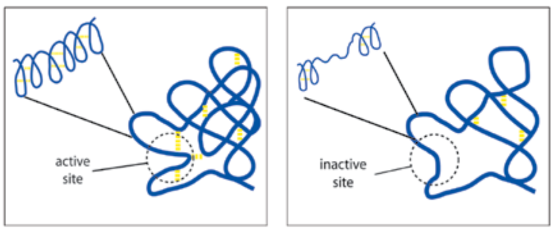
An enzyme is a protein that speeds up a chemical reaction millions of times faster than would occur without the presence of the enzyme. Enzymes are so efficient that they measurably accelerate chemical reactions, even at concentrations so low that they cannot be detected by most chemical tests for protein. Because they are not consumed during the chemical reaction, tiny concentrations are all that is required [4].

In the human body, the chemical reactions involved in the digestion of protein, fat and carbohydrate are all carried out with the help of enzymes [5], which break down the proteins, fats, and carbohydrates into smaller molecules that can be utilized at the cellular level [6].
These smaller molecules more easily traverse the mucosal lining of the intestines [7].

Environmental factors have an effect on enzyme activity. Enzymes are structured in living cells, but they can be isolated and remain active outside the living cell. Enzymes, therefore, are active both invivo and invitro. Many enzymes require the presence of an additional non-protein component, often a vitamin or a metal ion, to perform their function. By simply mixing the enzyme and the non-protein together, the fully active combinations can be constituted [4]. Enzymatic reactions can be disrupted by changes in pH and temperature [4,5]. Such changes can lead to an unfolding of the enzyme. This causes the enzyme to become inactive, referred to as denaturing the enzyme (Poisons and drugs can also inhibit enzymatic reactions) [4]



Phytate molecule in milieu of often tightly bound cat ion micronutrients forming phytin.



On the left is an enzyme with its active site where the enzymatic reaction occurs. The folded enzyme consists of a primary alpha helical chain (insert) which folds upon itself to form the active enzyme. The enzyme is held in this position by hydrogen bonds (yellow). When an enzyme is denatured (right) by excess heat or change in pH, hydrogen bonds are disrupted. The configuration of the enzyme's active site is changed, denaturing the enzyme and rendering it inactive.

Making Malted Barley

Malted barley is barley kernels that have been soaked in water and started on the path of germination, activating the enzymes that are present in the barley seeds making sugar, minerals, and amino acids available to the developing plant [6,8,9,10]. Once germinated over a relatively short time (generally around two days soaking followed by four days germination), the malt is kilned or heat dried. This drying is done in such a way that germination stops while the enzymes are preserved in their active state [4,8,10]. The resultant malt enzymes are no longer utilized as an enzyme source for the barley plant but rather as an enzyme system to pre-digest any available starchy food. This pre-digestion process releases sugar, soluble protein, amino acids, and bio-available mineral nutrients for enhanced nutrition or prevention of malnutrition in weanling infants as well as for the treatment of malnourished children and adults [6,10,12,13,14,15].

The Actions of PowerFlour's Enzymes

Amylases (Diastase)

Alpha-amylase enzymes and beta-amylase enzymes are present in barley malt [16,17]. Each attacks carbohydrate chains in a different way [15,16,18]. A combination of two or more amylases is called diastase. High diastatic malt contains higher than average levels of a combination of alpha and beta amylases. The function of amylase is to break down carbohydrates to maltriose, maltose, and glucose [2,16,19,20]. These sugars can be easily absorbed by the gastrointestinal tracts of infants and those suffering the ravages of severe malnutrition

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Alpha-amylase will maintain its potency up to 71 degrees centigrade (160 degrees Fahrenheit) [2,8]. Above these temperatures, the enzymes become denatured. Barley malt is kilned under controlled conditions so that the alpha-amylase is well preserved. The speed with which amylase acts accelerates linearly until the temperature of 72 degrees centigrade is reached [2].

The pH also affects the actions of amylase [2,19]. The pH range in which amylase has effective activity is between 4.8 and 7.0 [2]. This is well within the range of such starch-based foods as strained cereal (6.45), breadfruit (5.33), corn (5.90 – 7.30), cassava (4.5 – 6.5), cream of wheat-cooked (6.06 -6.16), oatmeal-cooked (6.20 – 6.60), white/Irish potatoes (5.10), millet (4.8 – 8.2), sweet potatoes (5.30 – 5.60), tubers (5.70), brown, white and wild rice-cooked (5.40 – 6.80), acorn squash –cooked (5.18 – 6.49), hubbard squash-cooked (6.00 – 6.20), white squash-cooked (5.52 – 5.80), yellow squash-cooked (5.79 -6.0), tapioca/manioc (5.9 -6.1), turnips (5.29 – 5.90) and yams-cooked (5.50 – 6.81) [21,22,23,24,25].

Proteases

The enzymes responsible for converting protein to soluble protein (short chain proteins or peptides) and amino acids are called proteases. This protease activity can make peptides and amino acids readily available for body maintenance, building and repair (the amount and presence or absence of each amino acid is dependent on the protein contained in the cereal grain being utilized).

There are four categories of proteases. All are present in barley malt - cysteine, serine, aspartic and metalloproteases [6,8]. They remain relatively active at temperatures up to 85 degrees centigrade (185 degrees Fahrenheit), therefore, surviving the malting process [8,10]. Each category of protease has its peak proteolysis activity at a different level of pH: 3.8, 4.8 and 6.0 [8] for cysteine, serine and the aspartic and metalloproteases, respectively, with activity taking place up to a pH of 8. Since only one category of protease is necessary to have effective proteolysis [6], PowerFlour's complex enzyme system is effective at the pH ranges of all the common starchy foods. The protease activity, like amylases, has been shown to be active in the mashing process of brewing, a process which strongly resembles the process of mixing malt into a hot starchy meal [11].

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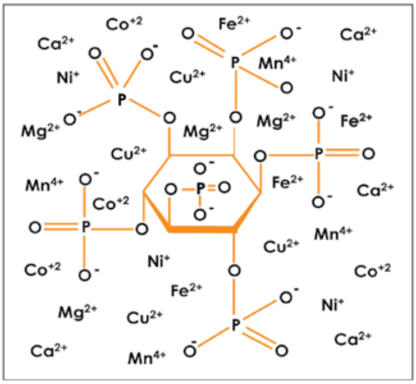
Phytases

Phytase, the third category of enzymes found in barley malt, is important because it breaks down phytate [27] (phytic acid) or more importantly, phytin. Phytate is negatively charged, and when it combines with positively charged ions (cations) it is called phytin. Many of the cations that are tightly held by phytates have significant nutritive value, including phosphorus, potassium, iron, copper, zinc, magnesium and manganese. Phytate is also an important source of stored phosphorus in cereal grains [28,29]. All of these micronutrients function as coenzymes that are essential to activate enzymes [30]. Phytate enables these minerals to be stored in cereal grains. However, a high concentration of phytate in food grain compromises mineral absorption in the gastrointestinal tract [31]. Mineral nutrients are all released from phytate by the phytase enzymes. The liberated cations are made available for use by the germinating seed and seedling. Phytase activity is increased 7.9 fold during germination [32]. This increased phytase activity is important in human nutrition because humans (and other animals with single lumen stomachs) don't make phytase [28]. Phytate is found in many cereals including barley, rice, millet, and corn as well as in soybeans. These phytates are degraded effectively by the phytase found in barley [32]. The degradation of phytate results in the release of sequestered phosphorus, iron, zinc, calcium, magnesium, manganese, and other minerals, making them bio-available.



Phytate molecule in milieu of often tightly bound cation micronutrients forming phytin.

There are two phytases in barley. The first has peak activity at 55 degrees centigrade (131 degrees Fahrenheit) and pH of 6.0. The second has peak activity at 50 degrees centigrade (122 degrees Fahrenheit) and pH of 5.0 [32]. The pH range of phytase activity has been shown to be 4.8 to 7.0 [33]. Phytase remains stable up to 100 degrees centigrade (212 degrees Fahrenheit) over the period of time used in mashing after kilning [34]. Thus, when germination is stopped and the barley malt is kilned and milled, the phytase remains active.

Mashing and the Preparation of Starchy Foods Supplemented with PowerFlour

Mashing is the process of mixing milled malted barley with cereal grain and water, heating this mixture up with “rests” at certain temperatures to allow enzymes in the malt to break down the starch in the grain into sugars and to promote proteolysis [9,10,11]. Single step infusion mashes (not having individual rests) most closely mimics the PowerFlour cooking techniques and is done between 62 and 67 degrees centigrade (143.6 to 152.6 degrees Fahrenheit) [18].

In Mexico, the Tarahumara Indians use a single stage mashing technique employing a product called Power Oat Flour (a combination of 10% PowerFlour and 90% oat flour). Water is added and the mixture is cooked with constant stirring much like single stage mashing [10] in a process similar to the way oatmeal is usually cooked. This brings the product from room temperature up to boiling, passing through the desired temperature range of 62 to 67 degrees centigrade [18] and eventually denaturing the amylases and the proteases at 72 degrees centigrade [8]. This process resulted in a meal that was lumpy and slow to liquefy. Knowing that an increased concentration of enzymes results in increased enzymatic activity over the same time frame, (the period when the product is between 62 degrees centigrade and 67 degrees centigrade), the mixture was increased to 15% PowerFlour. This ratio resulted in the desired liquid characteristics of the product and is indicative of an increased break down of the carbohydrate into sugars.

When preparing single meals with PowerFlour, the starchy gruel is first cooked. Then the PowerFlour is stirred into the mixture as the meal cools. The decreasing of temperature rather than increasing is different, but the progression through the appropriate temperature range for enzymatic activity occurs and the results are the same providing that a slight cooling after cooking is allowed to occur before adding the PowerFlour to the starchy food or porridge.

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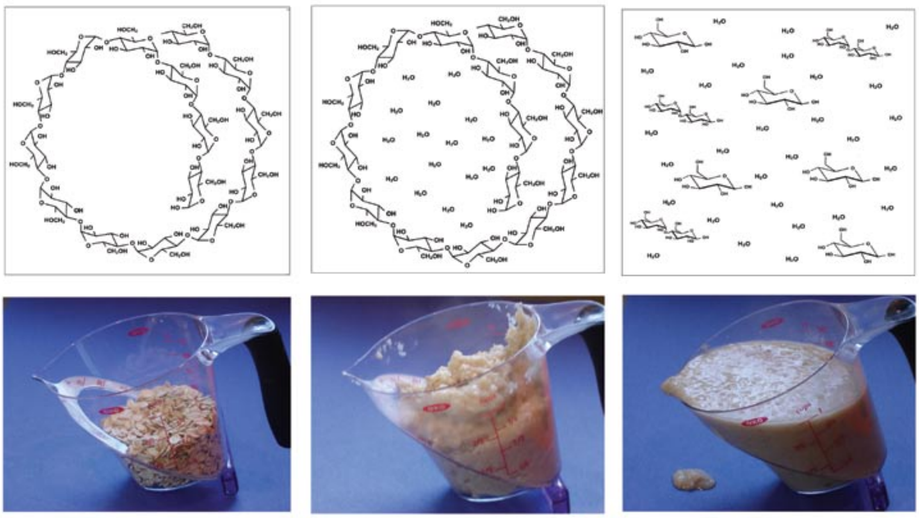
Liquefaction

Liquefaction of the starchy meals is an important function of PowerFlour. Many of the starchy foods are quite pasty and very difficult for infants and severely malnourished people to ingest. Enzymatic liquefaction solves this texture problem without the use of added water that reduces the caloric density of the product being consumed and may carry disease. To explain how liquefaction works, an understanding is needed of what happens when the starchy foods are cooked. The purpose of cooking a starchy food or porridge is to convert something that is difficult to eat into something that is easy to chew and swallow (dry oatmeal to cooked oatmeal, dry pasta to soft pasta). The easiest way to visualize the process is to first consider what happens when rolled oat flakes (oatmeal) are cooked with water. When the rolled oats are cooked, much of the original water is absorbed [35] into the flakes, held between its long convoluted carbohydrate chains, expanding it, gelatinizing it, making it soft and edible [36].

When amylase (diastase) laden PowerFlour is added to a starchy food, the carbohydrate chains are broken down into soluble carbohydrates and sugars, releasing the water, and causing the soluble carbohydrates and sugar to go into solution [19,37]. Because the semi-liquid food is easier to swallow and to digest, the breakdown of carbohydrates increases the amount of calories available to weanling infants and those suffering from moderate to severe malnutrition [38] (See the sections on the care of weanling infants and the care of the malnourished for further discussion). The soluble protein and amino acids produced by the proteases [6,8,9] also go into solution.

The importance of high diastase is demonstrated when comparing the high diastatic barley malt to millet malt which contains lower levels of alpha amylase. Adding millet malt to pap in Mali resulted in increased caloric bio-availability of the pap but did not change the fluidity of the food [38].



The picture and drawing of a complete carbohydrate on the left represent dry rolled oats. The center picture and drawing on the right reveals what happens when the rolled oats are cooked with water and with the addition of a small amount of high-diastatic milled barley malt. The meal becomes semi-liquid. The sugar is now suspended in the water which had been contained within the complex carbohydrate.

Use of PowerFlour in the Care of Weanling infants

The package of enzymes (amylases, proteases and phytases) provided by high diastatic milled barley malt – PowerFlour – can be used to the advantage of weanlings. Although the best and most desired source of nutrition is their mother's breast milk, there are many reasons why this ideal situation of having breast milk available to infants does not always happen. The mother may be ill or pregnant which may result in decreased or cessation of milk production. Absence of the mother resulting from separation or death also occurs at a frequency which often creates concern among health officials in developing countries. Another cause for premature cessation of breast feeding is the "first child – second child syndrome". This syndrome occurs when the mother of a breast feeding child delivers another child. Often the first child is prematurely weaned in order to provide breast milk to the new born.

When breast milk is not available to an infant, enzyme supplementation of the family's staple food is desired. Infants do not have the ability to produce the necessary enzymes and, therefore, cannot digest the starchy foods consumed by adults. All chemical reactions that occur during digestion require enzymes [39]. Glucose rather than complex carbohydrate is found in breast milk. Therefore, when breast milk is available, no amylase is required. Protein is found in breast milk, but proteases are present in the breast milk to digest the protein [40]. Therefore, when breast milk is available, no proteases are required.

Since neonates and infants don't make digestive enzymes [16,40], the absence of breast milk does not result in responsive enzyme production by the infant. Carbohydrates eaten by the adult human are digested by amylase produced in the saliva (ptyalin) and in the duodenum and jejunum by amylase produced by the pancreas. Thirty to forty percent of ingested starches can be broken down to maltose and glucose by ptyalin. The remainder is digested by pancreatic amylase [7]. Salivary amylase and duodenal (pancreatic) amylase production in the newborn is only 0.2% and 0.5% of the adult level, respectively [40]. The absence of amylase makes the bio-available caloric value of starchy foods quite low [16].

There has been an ongoing debate in the literature among medical professionals arguing by some that starchy foods be eliminated from the diets of infants until full dentition occurs (tooth eruption) which coincides with an infant's increased levels of ptyalin [16]. This generally occurs around two years of age [40].

Adding amylase to cereal food has been shown to increase the caloric bio-availability of the food (glucose and maltose). Malts without higher concentrations of amylases (diastase), as is the case with millet malt, when added to cereal porridges increases the caloric bio-availability of the food, but the fluidity of the cereal is not changed [38]. Addition of commercially manufactured amylase does the same [37]. However, non-food amylase is relatively expensive when compared with PowerFlour, and the flavor of the resulting food is often found to be unacceptable [36]. The use of high diastase barley malt addresses these issues. As seen in the Tarahumara experience, smaller amounts of PowerFlour will not result in a liquid meal much like that which occurs with the relatively lower diastase power millet malt. Larger proportions of PowerFlour will successfully convert the pasty/sticky cooked starchy mixtures into a semi-liquid gruel. Thus, the commonly consumed starchy foods of the developing world, if supplemented with PowerFlour, can provide readily available energy in a more palatable and easily ingested form.

The same circumstances are true for protein. The body does not store amino acids [5]. The essential amino acids and nitrogen required for body building, maintenance, and repair must be obtained from the diet on a regular basis. Protein digestive enzymes found in breast milk are able to compensate for the infant's immature gastrointestinal and pancreatic function [40]. The proteases found in PowerFlour carry out proteolysis that can effectively compensate for an infant's inability to carry out this digestive function.

The absorption of amino acids and soluble protein requires energy (which is supplied by glucose).Amino acids are not utilized for energy when sufficient amounts of glucose (and/or fat) are available. The amylases provide the energy component (sugar) necessary for the absorption of amino acids that are made available by the actions of the proteases. The provision of adequate sugar allows the amino acids to be utilized in the body's activities of building, maintenance and repair. If adequate supplies of sugar (energy) are not available, the amino acids are broken down into energy sources at the cost of the other essential activities [5].

Phytase enzymes are not synthesized by either children or adults [41]. Starchy foods frequently contain high phytate concentrations which bind nutritionally essential minerals, thus interfering with their absorption by the weanling or adult [41,42]. This contributes to the high incidence of mineral deficiency in infancy [41,43]. One aspect of food quality is the bio-availability of mineral micronutrients. Although the absolute level of minerals in food might be sufficient, their bio-availability is often restricted by high levels of phytate [29]. Phytases improve the nutritional values of plant-based foods (especially grains) by increasing the availability of the minerals bound by phytate [42,43,44]. Phytate degradation has been shown to improve mineral absorption from cereal porridges prepared with water, while in porridges made with milk, the destruction of phytate is blocked) [43].

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The Use of Power Flour in the Care of the Malnourished

Severe malnutrition results in the cessation of enzyme production, resulting in the same nutritional challenges described for the weanling infants. In order to understand the important role that a lack of digestive enzymes plays in the pathophysiology of malnutrition there needs to be some understanding of protein energy malnutrition (PEM). PEM is present when insufficient energy (sugar) or protein (soluble protein and amino acids) is available to meet metabolic demand [45].The basic metabolic response to starvation is conservation of energy and body tissue. However, in moderate and severe malnutrition, the body will mobilize its own tissues as a source of energy resulting in the destruction of visceral organs and muscle. The greatest loss in visceral weight occurs in the liver and intestines [46]. Blood glucose levels fall and are only maintained at a lower level by synthesis of glucose in the liver from amino acids released from muscle. As wasting proceeds, amino acid levels fall (with the essential amino acids decreasing more rapidly than nonessential amino acids) resulting in a decreased source for sugar production [47].

Glucose absorption potential of the intestinal tract increases in starvation and the intestinal response to dehydration is not altered [48]. The sustained absence of nutrients in the intestines results in structural and functional atrophy of the entire gastrointestinal tract [45,49,50]. With severe malnutrition, the production of digestive enzymes decreases [49,51] with a demonstrable decreases in volume and content of salivary, gastric, pancreatic, and intestinal enzymatic secretions [45,49,51,52]. Intestinal malabsorption of fat and micronutrients is common [48].

In treating malnutrition, the efficient utilization of dietary protein requires energy from nonprotein calories (sugar). As stated previously, protein synthesis is decreased. The amino acids are not efficiently incorporated into protein without other energy sources partly because of the energy lost during amino acid metabolism [53].Diets containing free amino acids and/or soluble protein, have an advantage over standard longer-chain proteins in patients with pancreatic exocrine insufficiency as occurs with malnutrition [51].

One of the major causes of death on initiation of treatment for malnutrition is low blood sugar levels or hypoglycemia. Sugar is the primary energy source for protein absorption and synthesis and, therefore, for the enzyme systems that support the maintenance, building and repairing of the body. While malabsorption of carbohydrate occurs [53], increased potential for absorption of sugar is a response to malnutrition [48]. Breaking down carbohydrate to sugars with the addition of PowerFlour to starchy foods is a great advantage to those with malnutrition. To prevent death from hypoglycemia, the severely malnourished need to be fed immediately with small meals that include sugar and available micronutrients provided every two hours [47]. Potassium, phosphorus magnesium and other micronutrients should be replaced liberally [47,51].

As was shown in the discussion of care for the weanlings for whom breast milk is unavailable, PowerFlour, a source of biologically active amylases, proteases, and phytases, is a potentially life-saving dietary additive. PowerFlour combined with the starchy foods commonly found in developing countries will increase the availability of sugars, soluble protein, amino acids, and mineral nutrients. These same deficiencies in digestive enzymes also occur in cases of severe adult malnutrition or starvation. The need for an available energy source to enhance protein absorption and synthesis, as well as the need for bio-available micronutrients has also been shown in poorly nourished adults such as those suffering from HIV/AIDS with its attendant medical complications [56].

Conclusion

PowerFlour can play an important and critical role in the care of weanlings and the malnourished. It works well with starchy foods or porridges commonly consumed as dietary staples in the developing world. It is safe. The costs are insignificant. Liquefaction and the increase in availability of sugar and calories for the weanlings and malnourished are a consistent result of adding PowerFlour to starch based foods. The increase in the amount of soluble protein, free amino acids and micronutrients that will result from the use of PowerFlour is more variable and primarily depends on the amount of protein and micronutrients contained in the starchy foods consumed.

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