# Tetrasodium Pyrophosphate

**Processing**

## Identification of Petitioned Substance

**Chemical Names:**
Tetrasodium pyrophosphate

**Other Names:**
Diphosphoric acid tetrasodium salt
Decahydrate tetrasodium pyrophosphate
Tetrasodium diphosphate
Sodium pyrophosphate
Tetrasodium phosphate

**Trade Names:** Tetrasodium pyrophosphate, anhydrous (Disodium diphosphate)

**CAS Numbers:**
7722-88-5

**Other Codes:**
ACX #X10000139-0
RTECS UX7350000

## Summary of Petitioned (Current) Use

Following a petition submitted in 2001 (USDA, 2001), the NOSB voted September 19, 2002 recommending the addition of tetrasodium pyrophosphate (TSPP) to the National List (NOSB, 2002 a). The final rule was published September 11, 2006 (Day, 2006; Electronic Code of Federal Regulations, 2013) as follows:

> § 205.605 Nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."
>
> (b) *Synthetics allowed:*
>
> Tetrasodium pyrophosphate (CAS # 7722-88-5)—for use only in meat analog products[1].

The NOSB reviewed and recommended TSPP for relisting at its November, 2009 meeting (NOSB, 2009). As required by the Organic Foods Production Act, the National Organic Standards Board has the responsibility to review each substance on the National List within five years of its adoption or previous review.[2] A previous technical report for tetrasodium pyrophosphate was completed in July, 2002 and is available on the NOP website (NOP, 2002). For the 2016 sunset review, the NOSB requested an updated limited scope technical evaluation report for TSPP covering new developments in the production of meat analogs. To support their decision-making the document has been limited to the following sections:

- Identification of the Petitioned Substance
- Summary of Petitioned (Current) Use
- Evaluation Question #11

[1] The term "meat analog" was originally used by the 2002 NOSB in the description of products prepared from wheat. Many meat analogs are grain based, e.g. soy or wheat (FEN, 1978). However, the term, meat analog can be extended to any product mimicking the primarily texture, flavor, appearance, mouth-feel and/or chemical characteristics of specific types of meat. Generally, meat analog is understood to mean a food made from non-meats, sometimes without other animal products, such as dairy (Kabuo et al., 2013). Meat analog also refers to a meat-based and/or less-expensive alternative to a particular meat product, such as surimi (Kim et al., 2005; Park, 2005).
[2] OFPA, Section 2118(e).

- Evaluation Question #12
- Evaluation Question #13

The current listing for tetrasodium pyrophosphate is scheduled to sunset on 9/12/2016. [3]

**Evaluation Questions for Substances to be used in Organic Handling**

**Evaluation Question #11: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).**

In the late 1800s, John Harvey Kellogg of Battle Creek, Michigan as part of his holistic research to develop a palatable meat free diet began producing meat analogs consisting of pastes of ground nuts, water, flour, cereals and other ingredients retorted to a solid mass. He also boiled wheat gluten to produce chewy expanded products that could be flavored with various spices and extracts. In 1907, Kellogg (U.S. Patent 869,371) patented a process for the fabrication of a comminuted meat-like product from mixtures of wheat gluten and casein (Kinsella, 1978). From this work, several methods were devised for texturizing food proteins: steam texturization, fiber spinning, thermal extrusion, chewy gel formation, extrusion, fiber formation and the other processes. A variety of palatable meat analog products are now available in the marketplace (Egbert and Borders, 2000). Many of them are produced without the use of tetrasodium pyrophosphate (TSPP).

A functional protein or a functional combination of proteins able to form a chewy meat-like gel forms the basis for any meat analog. For some proteins, e.g. gliadin and glutein from wheat, gel formation is achieved without additions simply by "working" and heating dough to develop the cross-linked product gluten, a functional ingredient for the meat analog seitan. Protein gels consist of protein aggregates connected to one another by intermolecular crosslinks. Protein functional properties like gelation, emulsification and water holding capacity provide meat analogs with their chicken, pork, beef, fish or duck chewy mouth-feel properties (Asgar et al., 2010).

Usu is a tribal food produced in Nigeria, with properties of a meat analog. It is made from ground melon (Egusi) seed (*Colocynthis citrullus L*) and ground big mushroom or erousu (*Lentinus tuber regium*). The dough used to produce it is mixed with other ingredients such as pepper, salt and spices, wrapped in different traditional packaging materials (leaves) depending on the production location and then cooked. No other conditioners are added (Kabuo et al., 2013).

Proteins extracted from soybeans consist mostly of glycinin and β-conglycinin. Thermoplastic gelation of these proteins by heating and extrusion at high pressure produces textured vegetable protein which currently used in many meat analog products (Nishinari et al., 2014; Horan, 1974). Gel formation depends on several physico-chemical factors including: temperature; pressure; ionic strength; pH; solvent quality; protein concentration, the extent of aggregate formation and the presence of enzymes that catalyze cross-linking e.g., transglutaminase, peroxidase and polyphenol oxidase (Bannerjee and Bhattacharya, 2012). Where one or more parameter does not meet requirements for gelation, water holding capacity or water activity, a food additive such as TSPP may be used.

TSPP is a synthetic food additive used in the manufacture of some meat analogs serving a number of purposes that compensate for insufficient gelling requirements. It can serve as a buffer to adjust pH (alkaline), as a coagulant, as a dispersing agent, as a protein modifier and as a sequestrant (Lampila and Godber, 2002). The effects TSPP has on food e.g., improving texture,

[3] The current list of sunset dates is available on the NOP website at [NOP 5611 – National List Sunset Dates]

reducing cooking loss and accelerating gelation are the result of TSPP's unique interaction with calcium and food proteins.

TSPP is basic in solution (pH 10.3), but is a good buffer component at pH levels slightly above pH 7.0. Calcium binding by protein is dependent on pH. Crystallographically, TSPP and calcium appear as dimeric tetrahedral (pyramidal) slabs arranged perpendicularly in six-way coordination with the calcium cation (Averbuch-Pouchot and Durif, 1996). In solution, the slab becomes more fluid, but the pyramids remain stable giving TSPP a fluid space filling property. At pH 7-8, in solutions of protein and TSPP, calcium is transferred from protein to TSPP catalyzing changes in protein structure caused by the entry of pyrophosphate slabs into protein folds and helices (Averbuch-Pouchot and Durif, 1996; Zayas, 1997).

TSPP sequesters or removes calcium from proteins that are known to be naturally associated with calcium, e.g. muscle tissue cells, soy protein. This is advantageous for meat analog production because calcium binding to protein can inhibit gelation. Under the right conditions which includes heating and pH adjustment, TSPP sequestration of calcium ($k_a$=557 x $10^{-3}$) causes a change in protein structure that increases the surface exposure of ionic residues (Bao et al., 2008; Mekeme and Gaucheron, 2011). The increase in surface ionic residues increases protein crosslinking, resulting in gelation and increased water holding capacity to the extent that controlled texturing is possible (Averbuch-Pouchot and Durif, 1996; Zayas, 1997). The same effect is obtained with specific proteins under specific conditions by heating alone.

Gelling properties of proteins determine the quality characteristics of many foods, especially textural properties and juiciness found in meat analogs. Gels are formed when partially unfolded proteins develop uncoiled polypeptide segments that interact at specific points to form a three dimensional cross-linked network. Partial unfolding necessary for gelation results from the action of various factors such as heating, or treatment with acids, alkali or denaturants. Many meat analogs are products of thermoplastic or irreversible gel formation by proteins from fish, soy, wheat, pea, milk, fungi, and others (Zayas, 1997). Not all proteins form thermoplastic gels, and those that do only do so at specific concentrations, pH and ionic strengths. Texturized protein products, the precursors of many meat analogs, are fabricated palatable food ingredients processed from an edible protein source. Texturized soy protein is by far the most used product in the production of meat analogs and can take the form of fibers, chunks, bits, granules, slices and others. Typically, textured protein products are produced by an extrusion process utilizing a specially configured extruder with a special die that can be used to convert vegetable protein sources directly into simplified varieties of meat analogs. The important properties of meat analogs are meat-like appearance, meat-like texture, meat-like mouthfeel, water absorption and cooking characteristics that are very similar to meat. These products have a striated, layered structure similar to that found in muscle tissue. Extrusion of texturized soy protein does not require the introduction of additives such as TSPP, unless the raw ingredients used have high oil or moisture levels, low protein quality or low protein concentration (Riaz, 2004).

Extrusion is an effective way of denaturing whey proteins to create texturized products (Onwulata, 2011). In one study, whey protein concentrate (WPC, 80%) was textured using twin screw thermoplastic extrusion to produce a textured whey protein patty. A patty containing 2.25 grams of egg white, 2 grams wheat gluten, 0.5 grams xanthan gum, 30 grams of textured whey protein, 45 grams water, and 3 grams vegetable base or 6 grams raw mushrooms and 3 grams raw mushroom base provided the most favorable sensory outcome (Taylor and Walsh, 2002). For many flour and protein sources, anti-nutritive properties, off-flavors, and other disadvantageous properties have been overcome allowing them to be processed by heat extrusion. Even pea protein can be heat extruded to form textured protein useful as a meat analog (Wang et al., 1999).

The thermosetting properties of hydrated gluten complement film-forming and adhesive properties, making gluten an option for meat, poultry and seafood analog applications. A major use of gluten is as a meat replacement in vegetarian foods, and in the production of artificial forms of expensive foods such as seafood and crab analogues. Pure wet wheat gluten can be seasoned, shaped, and cooked into meatball and steaks. Texturized wheat gluten developed using extrusion technology can be used to mimic the mouthfeel, chew, and taste of meat. 'Meat' products created by this process are suited to ready-to-eat entrees, as sandwich fillings, or for pizza and salad toppings (Day et al., 2006).

**<u>Evaluation Question #12:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).**

Meat analogs are manufactured from vegetable proteins. Protein functional properties and the control of these properties are very important in determining the usefulness of a specific protein, combination of proteins or flour in meat analog production. Table 1 provides a list of some of these properties.

Table 1 Typical Functional Properties of Proteins in Food Applications*

| Property | Examples of functional properties |
|---|---|
| Organoleptic | Color, flavor, odor, mouthfeel |
| Hydration | Solubility, dispersability, wettability, swelling, thickening, gelling, water-holding capacity, syneresis, viscosity, etc. |
| Surfactant | Emulsification, foaming, aeration, whipping, aeration, whipping, protein/lipid film formation, lipid binding, flavor binding |
| Structural or Rheological | Elasticity, grittiness, cohesiveness, chewiness, viscosity, adhesion, network cross-binding, aggregation, stickiness, gelation, dough formation, texturizability, fiber formation, extrudability, etc. |
| *These functions vary with pH, temperature, protein concentration, protein species or source, prior treatment, ionic strength, and dielectric constant of the medium, by processing treatment and by modification, etc. | |

*from* Kinsella, 1978

Natural (non-synthetic) substances or products can be used in place of alkaline phosphates in meat analogs, improving gelation, increasing protein water holding capacity and improving emulsion development and stability (Bannerjee and Bhattacharya, 2012; Godber and Lampila, 2002). In contrast, phosphates (diphosphates) have synergistic effects causing dissociation of protein complexes, increased stability of some proteins and decreased the stability of others.

Tetrasodium pyrophosphate (TSPP) also influences the strength of protein networks, which may lead to the dissociation of some proteins (Zayas, 1997).

The capacity of proteins to retain water is significantly affected by the ionic strength of the medium. The amount of water bound by proteins is influenced notably by the concentration of neutral electrolytes. Sodium chloride (NaCl) affects the water holding capacity of proteins and decreases water activity. NaCl and phosphates act synergistically (Godber and Lampila, 2002). Use of TSPP reduces the use of NaCl. Studies of the influence of various salts show that protein functionality is dependent on the balance of interactions between protein, water and salt. As the concentration of neutral electrolytes is reduced, the water holding capacity is increased (Zayas, 1997). At higher ionic strength, TSPP negates undesirable hydrophobic interactions (coagulation) that result from heating. TSPP enhances the effect of NaCl to increase the temperature of aggregation and the tendency to undergo syneresis, e.g., at pH 5.5 in the absence of TSPP syneresis, the separation of a gelled protein from liquid begins at 70$^{o}$C , but with same protein gel at pH 6.0 with TSPP added, syneresis is initiated at 87$^{o}$C (Godber and Lampila, 2002).

Alginates were reviewed by the NOSB and added to the National List in 1995 (NOP, 1995a). Alginates are natural synthetic substances that can be used in food processing as stabilizers, thickeners, gel forming agents and emulsifiers. These functional properties are attributed to alginate forming chemically induced rather than heat induced protein gels. Alginate gels are formed by the intermolecular association of polyvalent cations such as calcium with polyguluronate sites on the alginate molecule. Factors such as pH, temperature, alginate type, alginate concentration, calcium salts and the type of sequestrant used to bind calcium affect gelling. A model for sweet potato and the development of restructured products including meat analogs provides a good example of changing technology associated with the use of TSPP and alginate. Improvement of a home prepared sweet potato product containing a cellulose gum gelling agent was necessary because the gelling properties of this gum were thermally induced, and the product only retained its texture at elevated temperatures (Truong et al., 1995). In response, the investigators chose to add alginate and calcium sulfate to the sweet potato puree. Because the alginate gelling process requires the calcium concentration to be carefully controlled and sweet potatoes have a high level of endogenous calcium, TSPP was added as a calcium sequestrant to avoid products that gelled prematurely or were soft. This addition improved alginate gelling and optimization of gel texture. The final optimum TSPP concentration was found to be 0.12-0.18%, producing a stable commercial product (Walter et al., 1998; 2002, Truong and Avula, 2010). Natural products containing calcium binding proteins such as soybean protein hydrolysate might have been used to substitute for TSPP providing non-synthetic control of endogenous calcium prior to gelation with alginate (Bao et al., 2008). It may also be possible to add the enzyme transglutaminase potentially from a microbial source to enhance molecular network formation and improve alginate dependent gelation (Moreno et al., 2009).

Alginates are members of a class of substances called hydrocolloids. Defined as a suspension of particles in water where the particles are molecules that bind to water and to one another, hydrocolloid particles slow the flow of the liquid or stop it entirely, solidifying into a gel. Hydrocolloids possess additional functional properties such as thickening, gelling, emulsifying, gel stabilizing and others (Egbert, R. and Border, C., 2006). Hydrocolloids can be polysaccharides, glycoproteins or lipopolysaccharides and found in a variety of plants and microorganisms. They are extracted commercially using a variety of chemical methods and most often labeled as synthetics for the National list. A number of hydrocolloids are already on the National List such as xanthan gum (NOP, 1995b), carrageenan (NOP, 2011a), agar-agar (NOP, 2011b), gellan gum (NOP, 2008), guar gum (NOP, 1995c), locust bean gum (galactomannan—(NOP, 1995c)), Konjac flour (Glucomannan—(NOP, 2001)), pectin (NOP, 1995d; Cargill, 2014; NOP, 2011; ) and others.

They can be used in combination or separately to provide synergistic functionality in producing a variety of textured protein based food types.

Exopolysaccharides produced by deep sea marine bacteria and microorganisms are frequently hydrocolloids. As new organisms are discovered from oceanic sources new hydrocolloids have been elucidated. One high calcium binding polysaccharide was found that may one day be developed as a sequestrant for alginate gel formation (Poli et al., 2010).

Locust bean gum is a naturally-derived texturizing ingredient from the seed of the leguminous carob tree (Ceratonia siliqua), which is grown in Mediterranean countries. The carob seed consists of three different parts: the husk surrounding the seed, the germ (protein) and the endosperm (gum) – the locust bean gum is extracted from the endosperm. Locust bean gum significantly improves gel strength and texture and prevents syneresis when used in combination with carrageenans. Xanthan gum and locust bean gum in equal proportions at a concentration of 1% allow production of rubbery, elastic gels. Locust bean gum has a unique synergy with xanthan gum that provides clear advantages such as highly elastic gel formation from two thickening agents with a very limited syneresis (Cargill, 2014b). Lecithins are also used as emulsifiers and thickening agents (Archer Daniels Midland, 2005).

Xanthan gum has been used in a wide variety of foods for a number of important reasons, including emulsion stabilization, temperature stability, compatibility with food ingredients, and its pseudoplastic rheological properties. The polysaccharide B-1459, or xanthan gum, produced by the bacterium Xanthomonas campestris NRRL B-1459 was extensively studied because of its properties that would allow it to supplement other known natural and synthetic water-soluble gums. Extensive research was carried out in several industrial laboratories during the 1960s, culminating in semi-commercial production as Kelzan1 by Kelco1. Substantial commercial production began in early 1964. Today, the major producers of xanthan gum are Merck and Pfizer in the United States, RhoÃne Poulenc and Sanofi-Elf in France, and Jungbunzlauer in Austria (Garcia-Ochoa et al., 2000).

Gellan gum is a water soluble hydrocolloid produced by *Pseudomonas elodea*. Konjac glucomannan is a hydrocolloid and neutral polysaccharide produced from the tuber of *Amorphophallus konjac C. Koch*. When konjac flour is dissolved in an alkaline coagulant (such as calcium hydroxide, sodium or potassium carbonate), deacetylation occurs and a thermally stable gel is formed. The rate of gel formation is dependent upon pH and processing temperature. Konjac flour provides functional properties as a thickener and gelling agents. A combination of gellan gum and Konjac flour produces a good gelling agent for tetrasodium free meat analogs (Lin and Huang, 2003).

**<u>Evaluation Information #13:</u> Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR § 205.600 (b) (1)).**

Meat analog production may sometimes require the addition of starches, hydrocolloids and protein additives that are used as fillers and/or extenders in order to boost or alter some textural property. The palatability or sensory perception (tenderness, juiciness, mouthfeel) shared by meat products and meat analogs is influenced in process by formation of viscoelastic three-dimensional gel matrices via protein–protein interactions, binding water and forming cohesive, strong membranes on the surface of fat globules in emulsion systems or flexible films around the air–water interface. Proteins in hen egg white (ovalbumins) are often used as ingredients for meat analogs because of their unique functional properties including gelling, foaming, heat setting and binding adhesion. Ovalbumin is a globular monomeric phosphoglycoprotein containing free sulfhydryl groups (four, which are buried in the protein core). The ability of globular proteins to form heat-induced or cold set gels results from external exposure of sulfhydryl groups and hydrophobically driven protein–protein interactions. Ovalbumin provides a strong gel network in meat analogs (Weijers et al., 2002; Choi et al., 2008). Ovalbumin is available commercially dried as a powder that can be added to meat analog doughs to improve texture by increasing protein-protein binding strength (Lu and Chen, 1999). However, this alternative may not be acceptable when developing a vegan product.

Wheat gluten/seitan, tofu, soya meat, tempeh, cottonseed flour, mycobacterium (Quorn (*Fusarium venenatum* protein)), sweet lupines, algae (Remis-Algen Spezial Algenprodukte ), sprouted soybeans (Yaso), rice protein, pea protein, mushroom (Freshshrooms), soy-vegetable fibers (Proviand) and pecan, oats, cornmeal and garbanzo beans (Neat) are all ingredients that have been produced organically and used for the production of organic meat analogs without the use of tetrasodium pyrophosphate. Table 2 also provides a list of certified organic producers of meat analogs and textured proteins not currently using tetrasodium pyrophosphate.

Wheat gluten, also called seitan, is made by washing wheat flour dough with water until all the starch granules have been removed, leaving the sticky insoluble gluten as an elastic mass which is then cooked before being eaten. Wheat gluten used in meat analogs improves binding and texture. Thermosetting properties of hydrated gluten complement its film-forming and adhesive properties. Wheat gluten acts as a binder and provides a meat-like structure in 'veggie burgers'. (Day et al., 2006).

Tofu, also known as bean curd, is a food made by coagulating soy milk and pressing curds into blocks. Tofu skin is produced by boiling soy milk to produce a film or skin on the liquid surface. Tofu skin has a soft yet rubbery texture and can be folded or shaped into different forms and cooked further to imitate meat in vegan cuisine. Textured or texturized vegetable protein (TVP), also known as textured soy protein (TSP), soy meat, or soya chunks is a defatted soy flour product, a by-product of extracting soybean oil. It can be used as a meat analog. Tempeh is a traditional soy product originally from Indonesia made by a natural culturing and controlled fermentation process that binds soybeans into a cake. It has a firm texture, an earthy flavor and is used as a meat analogue.

Texturized mycelial protein extracted from the fungus *Fusarium venenatum* is used in the production of a popular meat analog

(Gadsby and Simmons, 1982). Sweet lupines are another source of protein flours that can be used in the production of an organic meat analog without the use of food additives. Like peanuts sweet lupines have the potential to cause severe allergic reactions.

Cottonseed flour has been in use as a meat extender and meat analog with textured soy protein. Combinations of textured soy protein and textured cottonseed protein are functional foods that can be produced without tetrasodium pyrophosphate (Cegla et al., 1977).

Many meat analog products are produced without tetrasodium pyrophosphate (TSPP). However, because this substance is generally regarded as safe (GRAS) when used in accordance with good manufacturing practice by the US Food and Drug Administration, it is possible that TSPP is used in a meat analog starting material (for example, soy meal) and then later combined into a product (e.g veggie burger) in which the listed ingredients only include the generic starting material (textured soy protein). This is because manufacturers can petition not to list a GRAS ingredient that is proprietary or is used at very low concentrations. Thus, TSPP may be an undisclosed ingredient in some products (FDA, 2014a, b, c, d, e; Damewood, 2014).

Table 2 Organic Meat Analog Producers*

| Company | Address | Telephone/FAX | Website |
|---|---|---|---|
| Amy's Kitchen Inc. | 1650 Corporate Cir Ste 200<br>Petaluma, CA 94954 | Phone: (707) 568-4500<br>Fax: (707) 570-0306 | www.amys.com |
| The Hain Celestial Group | 1111 Marcus Avenue<br>Lake Success, NY 11042 | Phone: 516-587-5204 | www.hain-celestial.com |
| Helen's Foods Inc | 1882 McGaw Ave Ste A<br>Irvine, CA 92614 | Phone: (480) 274-3284<br>Fax: (949) 797-0041 | www.helensfoods.com |
| Nexcel Natural Ingredients | PO Box 3483<br>Springfield, IL 62708-3483 | Phone: (217) 391-0091<br>Fax: (217) 391-0096 | www.nexcelfoods.com |
| Now Foods | 395 S Glen Ellyn Rd<br>Bloomingdale, IL 60108-2176 | Phone: (630) 545-9098<br>Fax: (630) 858-8656<br>Toll Free: (800) 999-8069 | www.nowfoods.com |
| Sol Cuisine | 3249 Lenworth Dr<br>Mississauga, ON L4X 2G6<br>Canada | Phone: (905) 502-8500, ext. 225<br>Fax: (905) 502-8100<br>Toll Free: (800) 370-8004 | www.solcuisine.com |
| Sunshine Burger & Specialty Food Co. LLC | 701 Jones Ave<br>Fort Atkinson, WI 53538-2118 | Phone: (920) 568-1100 | www.sunshineburger.com |
| Yves Veggie Cuisine | 1111 Marcus Avenue<br>Lake Success, NY 11042 | Phone: 516-587-5204 | www.yvesveggie.com |
| Surata Soyfoods | 325 West 3rd Avenue<br>Eugene, Oregon 97401 | Phone 541-485-6990<br>Fax 541-345-0758 | www.suratasoy.com |
| Lalibela Farm | 88 Carding Machine Rd<br>Bowdoinham, Maine 04008 | Tel: (207) 666-8788 | www.lalibelafarmmaine.com |
| Turtle Island Food, Inc. | PO Box 176,<br>Hood River, OR 97031 | Phone: 800-508-8100 ext 19<br>Fax: 541-386-7754 | www.tofurky.com |
| The Tempeh Shop | 1932 NE 23rd Avenue<br>Gainesville, FL 32609 | 352-275-6400 | www.tempehshop.com |
| Rhapsody Natural Foods | 752 Danville Hill Road<br>Cabot, Vermont 05647 | 802-563-2172 | rhapsodynaturalfoods.com |
| Frankferd Farms Food, Inc. | 717 Saxonburg Blvd.<br>Saxonburg, PA. 16056 | 724-352-9500<br>724-352-9510 | www.frankferd.com |

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