Miraculin

Miraculin is a natural sugar substitute, a glycoprotein extracted from the fruit of *Synsepalum dulcificum*.*[2] The berry, also known as the miracle fruit, was first documented by explorer Chevalier des Marchais, who searched for many different fruits during a 1725 excursion to its native West Africa.

Miraculin itself is not sweet. However, after the taste buds are exposed to miraculin (which binds to sweet receptors on the tongue), acidic foods which are ordinarily sour (such as citrus) are perceived as sweet. This effect lasts up to an hour.*[3]

The active substance, isolated by Prof. Kenzo Kurihara (栗原堅三 *Kurihara Kenzō*),*[4] a Japanese scientist, was named miraculin after the miracle fruit when Kurihara published his work in *Science* in 1968.*[5]

1 Glycoprotein structure

Miraculin was first sequenced in 1989 and was found to be a glycoprotein consisting of 191 amino acids and some carbohydrate chains.*[6]

Miraculin occurs as a tetramer (98.4 kDa), a combination of 4 monomers group by dimer. Within each dimer 2 miraculin glycoproteins are linked by a disulfide bridge.*[7]

The molecular weight of the glycoprotein is 24.6 kDa including 3.4 kDa (13.9% of the weight) of sugar constituted (on molar ratio) of glucosamine (31%), mannose (30%), fucose (22%), xylose (10%) and galactose (7%).*[2]

The taste-modifying protein, miraculin, has seven cystein residues in a molecule composed of 191 amino acid residues. Both tetramer miraculin and native dimer miraculin in its crude state have the taste-modifying activity of turning sour tastes into sweet tastes.*[9]

2 Sweetness properties

Miraculin, like curculin (another taste-modifying agent), is not sweet by itself, but it can change the perception of a sour beverage into a sweet beverage, even for a long period after consumption. The anti-sweet compound Gymnemic acid suppresses the sweet taste of miraculin, like it does for sucrose. *[7] The duration and intensity of the taste-modifying phenomena depends on various factors —miraculin concentration, duration of contact of the miraculin with the tongue, and acid concentration. Maximum sweet-induced response has been shown to be equivalent to the sweetness of 17% sucrose solution.

Glycoprotein is sensitive to heat: when heated over 100 °C, miraculin loses its taste-modifying property. Miraculin activity is inactivated at pH below 3 and pH above 12 at room temperature. The sweet modifying effect stays at pH 4 (in acetate buffer), for 6 months at 5 °C.*[2]

The detailed mechanism of the taste-inducing behaviour is still unknown. It has been suggested that the miraculin protein can change the structure of taste receptors on the cells of the tongue.*[10] As a result, the sweet receptors are activated by acids, which are sour in general. This effect remains until the taste buds return to normal. The two histidine residues (i.e. His30 and His60) appear to be mainly responsible for the taste-modifying behavior.*[11] One site maintains the attachment of the protein to the membranes while the other (with attached xylose or arabinose) activates the sweet receptor membrane in acid solutions.*[7] Further research is being conducted at the University of Tokyo using a system of cultured cells that allowed the testing of human taste receptors at various pH values to uncover the mechanism. As already known, miraculin binds strongly to the sweet taste receptors on our tongues; however, it does not activate receptors at neutral pH. Once acid is introduced, the miraculin protein changes shape in such a way that it turns on the sweet receptors it is bound to, causing an ultra-sweet sensation without affecting other flavors tasted. Once the acidic food is swallowed, miraculin returns to its inactive shape until the next acidic food comes along. This can continue for about an hour while the miraculin protein is still bound to the taste receptor.*[12]

3 As a sweetener

As miraculin is a readily soluble protein and relatively heat stable, it is a potential sweetener in acidic food (e.g. soft drinks). Japanese researchers' more or less successful attempts to mass-produce it are focused on recombinant technology. While attempts to express it in yeast and tobacco plants have failed, researchers have succeeded in preparing genetically modified *E. coli* bacteria,*[13] lettuce*[10]*[14] and tomatoes*[15] that express miraculin. The scientists' crops resulted in 40 micrograms of miraculin per gram of lettuce leaves, which was considered a large amount.*[10] Two grams of lettuce leaves produced roughly the same amount of miraculin as in one miracle fruit berry.*[16]

Miraculin was never approved for use as a sweetener by the United States Food and Drug Administration (FDA). In the 1970s the Miralin Company planned on bringing miraculin to market and was founded with investments by Reynolds Metals, Barclays, and Prudential. Legal advice and contact with the FDA indicated that miraculin would be approved as generally recognized as safe (GRAS), as the berries had been eaten for centuries in Africa with no reports of adverse reactions (substances used in food prior to January 1, 1958, through either scientific procedures or through experience based on common use in food can be designated GRAS). However, on the eve of the product's launch in 1974, the FDA determined that miraculin would be considered a food additive and thus require years of further testing. At that point, the company's investment capital could not sustain it and Miralin folded. Afterward, Miralin requested the FDA documents under the Freedom of Information Act. The documents were nearly completely blacked out, and the rationale for the sudden change in regulation was not revealed.*[17]*[18]*[19]

Miraculin has a novel food status in the European Union.*[20] However it is approved in Japan as a harmless additive, according to the List of Existing Food Additives published by the Ministry of Health and Welfare (published by JETRO).

4 Limitations

Miraculin is a non-heat-stable protein, subject to denaturation from heating, and thus miracle berries are not taste-bud active when cooked.*[10]

While miraculin changes the perception of taste, it does not change the food's chemistry, leaving the mouth and stomach vulnerable to the high acidity of some foods, such as lemon juice, that may cause irritation if eaten in large quantities.*[10]

5 See also

- Brazzein
- Curculin
- Monellin
- Thaumatin
- Pentadin
- Cynarin
- Stevia

6 References

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[10] Rowe, Aaron (2006-12-07). "Super Lettuce Turns Sour Sweet". Wired Magazine. Retrieved 2008-07-22. Sweet receptors sit on taste buds and wait for sweet molecules to come along and set them off," explained Göran Hellekant, a miraculin researcher and professor of physiology and pharmacology at the University of Minnesota. "Normally, they can only be set off by chemicals that are legitimately sweet, but miraculin may distort their shape a bit so that they become responsive to acids, instead of sugar and other sweet things.

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7 External links

- Miracle Mystery Fruit Turns Sourness Sweet on NPR
- Miracle berry lets Japanese dieters get sweet from sour
- Documented tasting experiment
- Protein Database Page
- Miracle Fruit's Trippy Effects Explained

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