Natto - Traditional Japanese Fermented Soy Beans with Recently Discovered Health Benefits and Novel Industrial Applications

An early form of natto was first produced in China over one thousand years ago by soaking steamed soy grain containing *Aspergillus oryzae*; however, this prototype natto did not have the sticky like texture of traditional Japanese natto. According to legend the first person to develop traditional Japanese natto was the famous warrior Yoshiie Minamoto during the Heian era of Japanese history (794-1192). As in western feudal warfare, the horse was extremely important to the Japanese samurai warrior of the period. Great care was taken to provide suitable provisions for horses when armies were on the move. Usually boiled soy beans were cooled down, dried in the sun and packed in straw bags for transport with the army; if the army had to move quickly, the boiled soy beans were packed immediately into straw bags without cooling and drying. If the straw happened to contain certain microorganisms the soy beans would undergo fermentation and produce the characteristic sticky texture now associated with natto. This was thought to mean that the soy beans were spoiled until Yoshiie Minamoto found that the fermented soy beans were not only edible but had a distinct Umami flavor. Minamoto was then responsible for introducing natto to the northwestern section of Japan where he ruled. To this day natto is especially popular in that region of Japan.

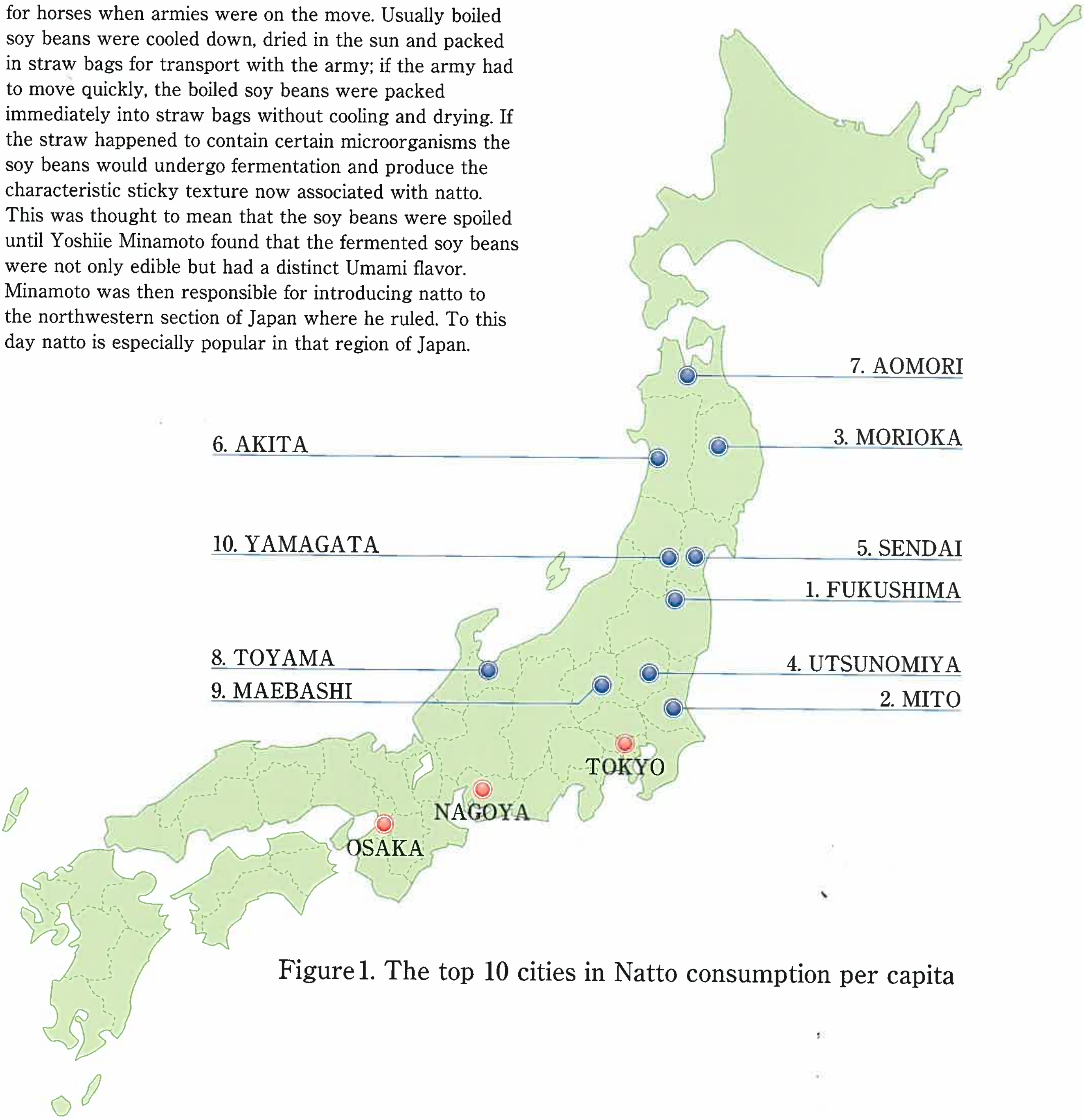
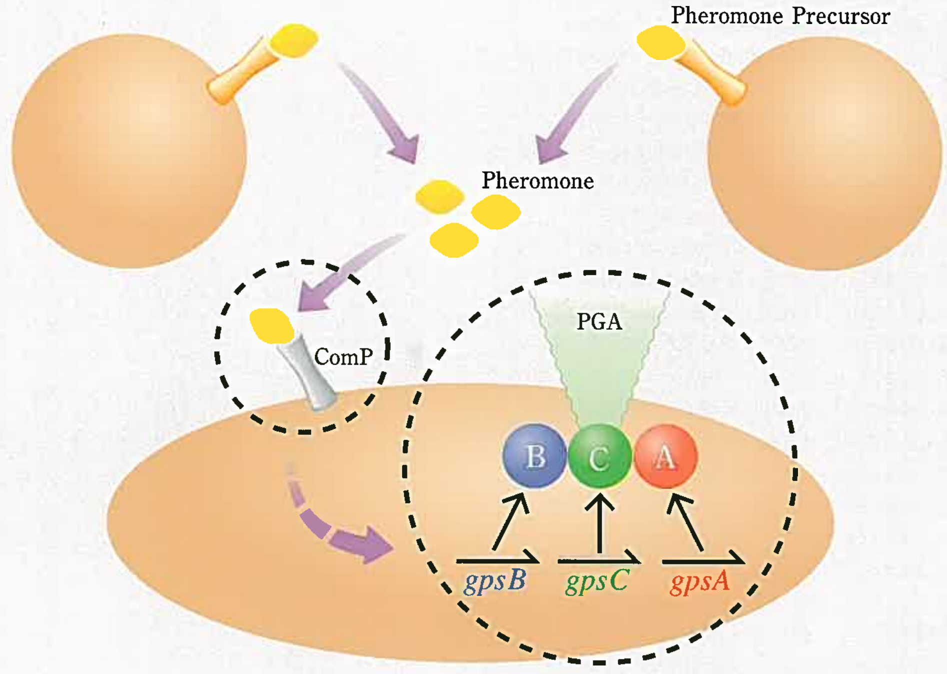


Figure 1. The top 10 cities in Natto consumption per capita

Figure 2. Stimulation of PGA production by Pheromone



It has been known for some time that natto has significant nutritional benefits. Natto is very rich in protein and amino acids; especially glutamic acid, an essential amino acid, which is present in rice at very low levels. Therefore the traditional Japanese breakfast of rice and natto is a very good combination. Natto also contains ten times the amount of vitamin B2 as soy beans because the fermentation process synthesizes vitamin B2. In addition, natto is rich in vitamin B1, B6, nicotinic acid, calcium phosphate and potassium. Despite increasing western influence on the Japanese diet, a number of diseases prevalent in the West, including coronary heart disease, breast cancer and prostate cancer remain much less prevalent in Japan. Recently, the presence of isoflavone and angiotensin I converting enzyme (ACE) inhibitor have been found in natto. These compounds are felt to play an important role in protection against these diseases and natto and soy products are thought to be excellent sources of these compounds. Natto-kinase present in natto was first described in 1987 and was shown to decrease blood clots in blood vessels of dogs. The results of human clinical studies indicate that natto-kinase may help increase thrombolytic activity and guard against myocardial infarction and senile dementia.

The sticky like texture of natto is a very important characteristic and has recently been the focus of molecular analysis. The material responsible for the sticky texture of natto is polyglutamic acid (PGA), a polymer containing both D-glutamic acid and L-glutamic acid. The production of PGA is highly sensitive to fermentation conditions and the ability of ***Bacillus subtilis*** to produce PGA is often unstable. It is now understood that two types of enzymes, glutamate racemase and glutamyltransferase, and three genes, ***gpsA***, ***gpsB*** and ***gpsC*** are responsible for the synthesis, regulation and secretion of PGA. Glutamate racemase is responsible for the conversion of L-glutamic acid to D-glutamic acid; since ***Bacillus subtilis*** lacking glutamate racemase has a reduced level of PGA, it appears that both D- and L- glutamic acid are required for the sticky like texture of natto. Glutamyltransferase is the enzyme responsible for the polymerization of both D- and L- glutamic acid. The gene products of ***gpsA***, ***gpsB*** and ***gpsC*** area thought to form a protein cluster on the surface of ***Bacillus subtilis*** cell membranes and to be involved in the regulation or secretion of PGA.

PGA synthesis during natto production is observed after 16 h of fermentation (40℃) during the stationary growth phase. The growth phase regulation of PGA synthesis is controlled by a 10- amino acid peptide pheromone containing modified tryptophan residues that is processed from the C-terminus of a precursor protein (comX) located in the *Bacillus subtilis* membrane. The secreted pheromone accumulates in the growth medium and reaches a concentration during stationary growth phase that is sufficient to activate the regulatory system. The genes *gpsA*, *gpsB* and *gpsC* are regulated by the pheromone activated signal pathway (Fig. 2) One explanation for the instability of PGA production by *Bacillus subtilis* is thought to be the inactivation of the pheromone receptor gene (*comP*) by insertion of a small IS element; the *comP* gene appears to be a hot spot for IS element insertion.

A number of very interesting industrial applications have emerged utilizing PGA. Irradiation of PGA with gamma rays cross-links PGA molecules producing a resin that can very efficiently trap water by forming a transparent hydrogel. Under optimal irradiation conditions the resulting PGA resin can hold 5000 times its own weight in water. This is five times the absorption capacity of commercial diapers and sanitary napkins. Because of its high capacity to hold water, PGA resin is being evaluated as an aid in reclaiming desert areas. Currently desert regions constitute 16% of the earth's land area and growing at a rate of 60,000 km^2 per year. Technology that will regenerate agricultural land from desert will play a very important part in improving mankind's future. PGA resin has also been used to clean waste water. The addition of PGA resin to waste water coagulates solid waste that can easily be removed as flock; indeed, PGA resin was recently used to clean water in the moat of Osaka castle. Another interesting application is the addition of PGA resin to concrete which lowers the density of concrete without a loss in strength.

It is truly astounding that such varied industrial applications and the identification of compounds with such significant health benefits can come from basic research of a traditional Japanese fermentation food.