

Jungbunzlauer

From nature to ingredients®

facts

Glucono-delta-Lactone in silken tofu



Introduction

Long gone are the days when soy products like tofu and bean curd were eaten only in Asia. They have also been finding their way onto the shelves of Western food outlets for decades now. And as health and sustainability awareness continue to grow alongside concerns about animal welfare, soy products are gaining significantly in market share and shelf prominence. After soy drinks the most familiar product is tofu, with growth in the market recently being driven by the constant launch of innovative tofu-based products like burgers, ice creams, shakes and desserts, as well as raw tofu.



Tofu itself consists mainly of water, soy protein, fat, and minerals and is therefore an excellent source of protein, especially for vegetarians, vegans and flexitarians. Since the protein profile of soymilk is considered to be one of the best among foods of plant origin, tofu represents an outstanding alternative to meat or milk products.^[1]

Tofu comes in many different forms. It can be natural or smoked. It can be flavoured with spices, herbs and nuts. It also comes in several textures: extra firm, firm, soft and silken tofu. This last has the softest texture and is characterised by a very smooth mouthfeel, almost like yogurt. Its mild taste makes it suitable for both savoury and sweet dishes. The unique texture of silken tofu is achieved by adding coagulants such as Glucono-delta-Lactone or calcium sulphate. In contrast to firmer tofu products, silken tofu production does not include a pressing step. As a result more whey is bound in the product, giving the silken tofu its particular texture.

This *facts* article advises how best to use Jungbunzlauer Glucono-delta-Lactone to obtain a high yield of silken tofu characterised by a pleasant firmness and increased breaking strength.

Glucono-delta-Lactone – a fermentation-based mild acidifier

Glucono-delta-Lactone (GdL) is a neutral cyclic ester of gluconic acid formed by the removal of water. Gluconic acid is an organic acid occurring naturally in plants, fruits and other foodstuffs such as wine (up to 0.5%) and honey (up to 1%).

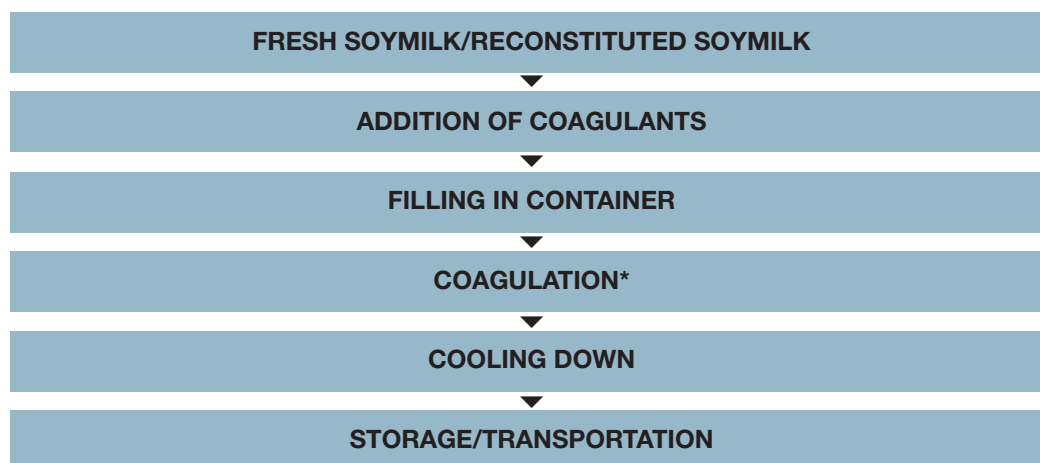
Jungbunzlauer's gluconic acid is produced by aerobic oxidative fermentation of glucose syrup from non-GMO maize. GdL is obtained by direct crystallisation from the aqueous solution of gluconic acid, resulting in a fine, white, crystalline powder. GdL is practically odourless and has a slightly sweet taste. Being non-toxic, it is metabolised completely in the body, like a carbohydrate.

When added to an aqueous solution, GdL dissolves rapidly. It hydrolyses slowly to gluconic acid to provide mild acidification. The decrease in pH is progressive and continuous until equilibrium, which makes it an outstanding acidifier compared to other acidulants, which tend to provide instantaneous acidification. The initial sweet taste of GdL becomes slightly acidic during hydrolysis. However, the final flavour of an aqueous solution of GdL remains much less tart than that of other common food acids (the relative sourness of gluconic acid is only one-third that of citric and lactic acids and a quarter of that of acetic, malic and tartaric acids).

Production of silken tofu

The production of tofu starts with fresh or reconstituted soymilk. Soymilk is won by soaking soy beans in water, grinding them, and filtering the liquid. Only soymilk high in protein is suitable for the production of tofu products. Soymilk can also be processed to powder by spray-drying and later reconstituted.

Figure 1: Production chart of silken tofu



*Coagulation temperature and time depending on coagulants used

The fresh or reconstituted soy milk is pasteurised and cooled to room temperature before coagulants are added while agitating the mixture. This is then filled into containers for immediate in-place coagulation. The containers are closed and heated to catalyse coagulation. Once this has taken place the containers are cooled and the silken tofu is ready for consumption or storage.

Coagulants for silken tofu

The coagulants added to soy milk to form a curd can be salts or acids. Tofu coagulants can be divided into four major groups: nigari-type or chloride-type coagulants, sulphate-type coagulants and acid coagulants, including Glucono-delta-Lactone. Different coagulants are used for different types of tofu. Nigari, for example, which is simply sea water and was traditionally used to prepare tofu, is most suitable for firm or extra firm tofu. It mainly consists of magnesium chloride, which is still used nowadays, but in purified form. Another commonly used coagulant is calcium sulphate, which belongs to the sulphate-type coagulant group. Of the acid coagulants, GdL is best suited to preparing soft and silken tofu. Sometimes mixtures of different coagulants are used and synergistic effects have been reported.^[1]

The coagulants named differ with regard to their coagulation mechanism. Pasteurisation of soy milk leads to an initial denaturation of soy proteins and the heat treatment exposes the hydrophobic regions which in the native state of the proteins are hidden.^[1] As a progressive acidifier, GdL slowly decreases the pH and releases hydrogen ions to neutralise the denatured proteins, inducing their aggregation.^[2,3] Hence gelation with GdL produces smooth tofu with a homogenous structure, whereas acid coagulants such as vinegar or lemon juice, which decrease the pH instantly, give rise to a crumbly, curdled tofu structure.

Chloride-type coagulants also release ions which aggregate proteins and form the soy curd, but here too aggregation is immediate and rapid. Thus the tofu obtained using this coagulant group has a spongy texture. GdL is unique in dissolving slowly to release acid progressively, enabling the production of all kinds of protein products with smooth, pleasant textures.

How to produce silken tofu using Glucono-delta-Lactone

The variables that determine the quality of silken tofu differ immensely, as do the available production parameters. All raw materials, but especially soybeans, vary in respect of origin, age and quality. Key to the quality of tofu are protein content and composition. In addition, the temperature at which soy milk is processed for tofu production, as well as the type, concentration and amount of coagulants used, have major impacts on its texture.

With this in mind, Jungbunzlauer has drawn up support and guidance for producers of silken tofu including recommendations for the optimal use of GdL. Our recommendations are substantiated by texture analysis and rheological measurements of silken tofu produced from fresh soymilk, as shown in the following sections.

Is gluconic acid suitable for silken tofu production?

Gluconic acid, the completely dissolved form of Glucono-delta-Lactone, is not suitable for production of silken tofu. It provokes an immediate pH drop and rapid acidification resulting in a crumbly curd, which is unsuitable for silken tofu.



What is the best way to add Glucono-delta-Lactone to soy milk?

For silken tofu production Jungbunzlauer recommends 0.26% GdL (granulation F5010) based on soymilk weight. If GdL F5010 is added directly to soy milk the resultant tofu may be streaked with holes and have an uneven appearance due to locally concentrated GdL hydrolysis. The best way to prevent this is to add GdL as a solution. Mix one part GdL with ten parts water and stir for 10 - 30 minutes. Add the mixture to soy milk at room temperature, then allow to gel for 45 minutes at 90 °C/195 °F. This ratio of GdL to water in combination with the recommended mixing time was shown to deliver the firmest and most stable tofu. At a ratio of 1:3 GdL hydrolysis was insufficient and holes were formed, whereas a ratio of 1:5 resulted in inhomogeneous tofu with an uneven, brittle surface. The ratio of 1:10 GdL in water ensures proper GdL hydrolysis and protein gelling, producing silken tofu with a smooth surface (figure 2).

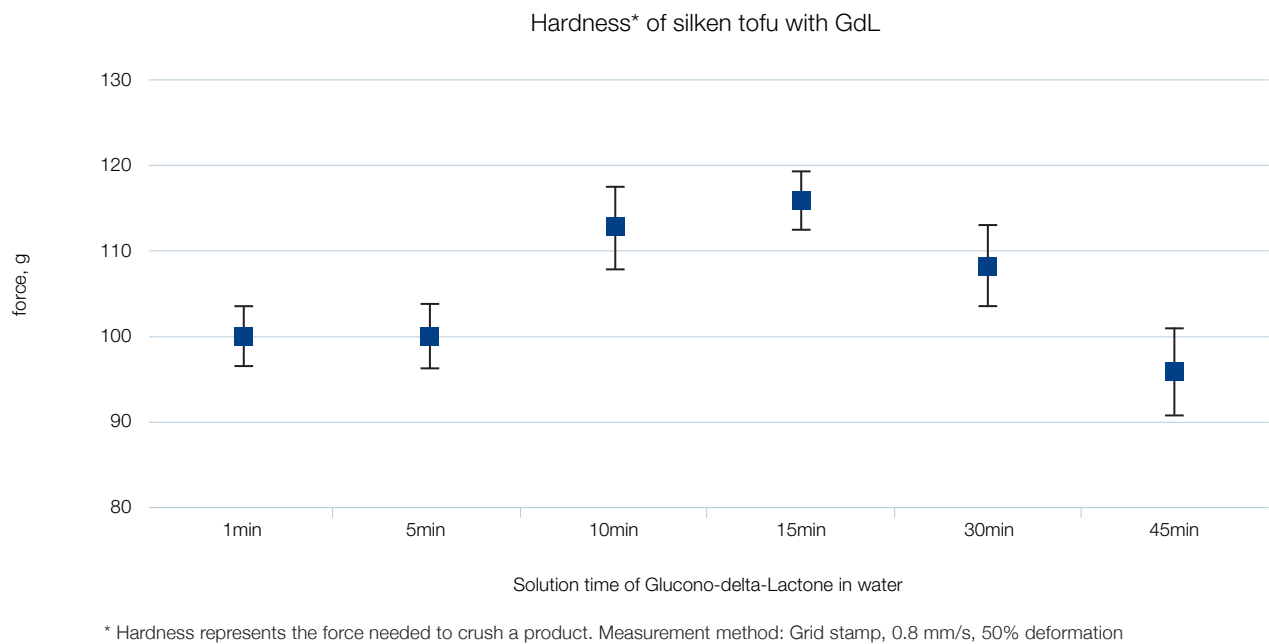
Figure 2: Silken tofu made from GdL solutions in water with ratios 1:3 (left), 1:5 (middle) and 1:10 (right)



Achieving the best texture and stability of silken tofu with Glucono-delta-Lactone

Silken tofu was prepared from GdL solutions that were stirred for 1 - 45 minutes. Five batches of silken tofu were produced from every solution and measured for their hardness using a texture analyser. Figure 3 shows the firmest silken tofus were obtained when the GdL solution was stirred for 10 - 30 minutes, whereas shorter or longer times resulted in softer tofu. A similar trend was observed when analysing the breaking strength of these same samples (data available on request).

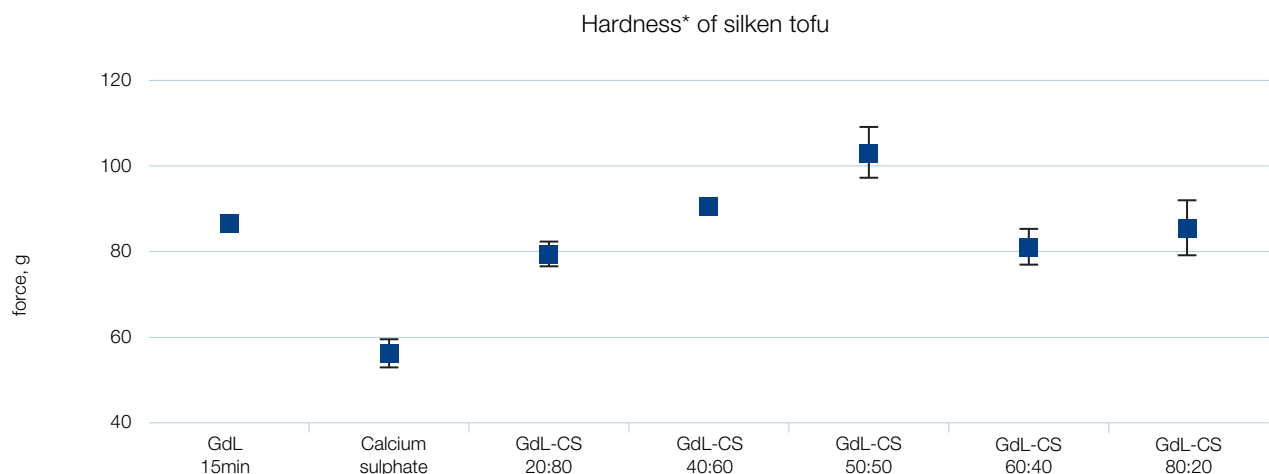
Figure 3: Hardness of silken tofu made from different Glucono-delta-Lactone solutions



How does Glucono-delta-Lactone perform in comparison to other coagulants?

Calcium sulphate is another well-established coagulant and widely used. Silken tofu was prepared with 0.26% GdL, with 0.4% calcium sulphate or with combinations of both in varying ratios (total coagulant concentration 0.3%). The hardness of the tofu obtained using the single coagulants or the mixtures was analysed (figure 4). GdL produced firmer tofu than calcium sulphate when using soymilk taken from the same batch. This confirms reports by Cheng et al. (2005).^[4] A combination of the two coagulants at a ratio of 50:50 led to increased firmness. This finding suggests that the hardness of silken tofu produced traditionally with calcium sulphate can be enhanced by a partial replacement with GdL.

Figure 4: Hardness of silken tofu made from 0.26% GdL, 0.4% calcium sulphate and 0.3% combinations thereof



The combination of calcium sulphate with GdL was further investigated based on rheological measurements including a comparison to nigari, as another widely used coagulant. Figure 5 shows the results of the amplitude sweep determining storage modulus G' at yield point. The yield point is defined as the end of the linear viscoelastic range and the minimum force that must be exceeded in order to break down a sample's structure at rest and thus make it flow. After this point a sample is irreversibly destroyed. Storage modulus at yield point can be consulted to obtain information about the structure strength and hardness of the tofu sample (figure 5).^[5]

Figure 5: Solid behaviour G' at yield point of silken tofu prepared with different coagulants

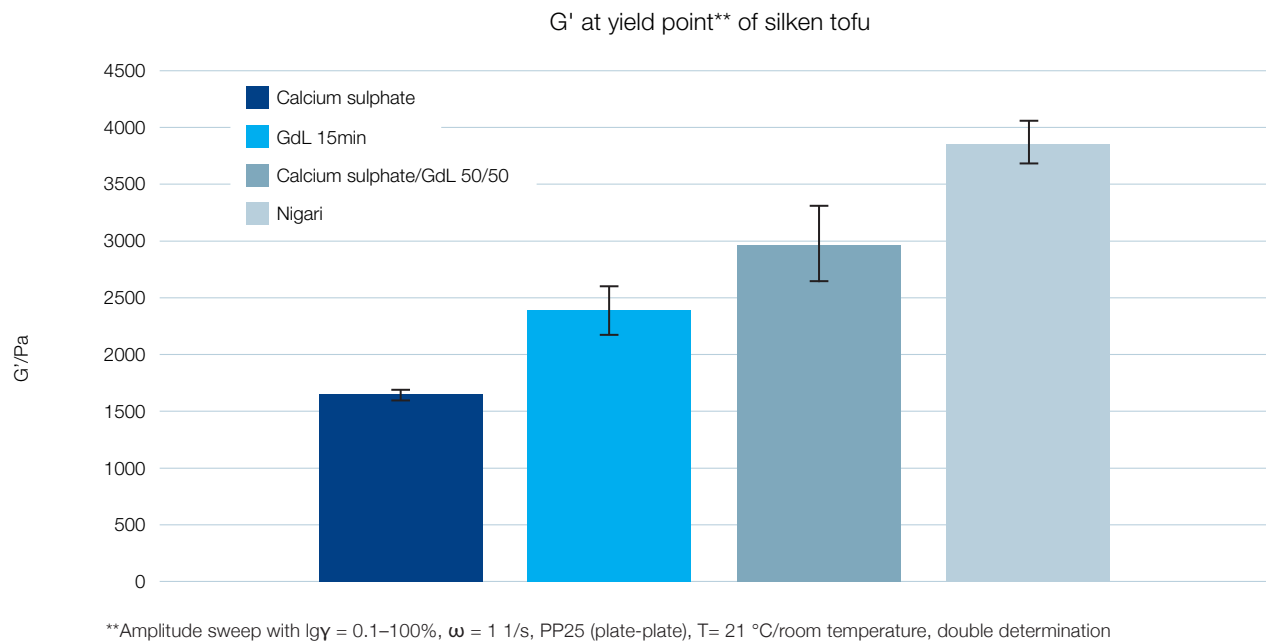


Figure 5 confirms once again that silken tofu prepared with GdL is firmer than that obtained with calcium sulphate, whilst a combination of the two coagulants results in an even higher value. Nigari tofu had the firmest structure in this measurement, due to its immediate, rapid coagulation of soy protein and strong whey separation. However, nigari is not suitable for the production of silken tofu because of its fast reaction time, which makes it difficult to achieve the smooth, uniform blocks desired for silken tofu.^[6]

Legal aspects of Glucono-delta-Lactone use

In the European Union, GdL is a generally permitted food additive (E575). It may be added to all foodstuffs, following the “quantum satis” principle, as long as no special regulation restricts the use (Regulation (EC) No 1333/2008).

The US Food and Drug Administration (FDA) assigned GdL the “generally recognised as safe” (GRAS) status and permits its use in food without limitation other than current good manufacturing practice (GMP) (CFR Title 21 Ch. I Sec. 184.1318). Among others, GdL may be used as a curing and pickling agent, pH control agent and sequestrant (CFR 21 Ch. I Sec. 184.1318(c)(1)).

In the International Numbering System of the Codex Alimentarius GdL has the INS number 575 and is categorised as an acidifier/acidity regulator as well as a raising agent.

The Acceptable Daily Intake (ADI) of GdL has been classed as “not specified” by the Joint Expert Committee on Food Additives (JECFA) of the FAO/WHO and the Scientific Committee for Food (SCF) of the European Community.

Purity criteria have been laid down for GdL by the main food and pharmaceutical compendia like the Food Chemicals Codex (FCC), the specifications of JECFA, Japan's Specifications and Standards for Food Additives (JSFA) and the US Pharmacopoeia, etc.

Summary

This *facts* article provides guidance on using Jungbunzlauer Glucono-delta-Lactone to obtain a high yield of silken tofu characterised by a pleasant firmness and increased breaking strength.

For high-quality silken tofu, Jungbunzlauer recommends using Glucono-delta-Lactone of the granulation grade F5010. Granulation size plays an important role in the dissociation rate of GdL and it was found that F5010 yields the most desirable dissociation rate. The smoothest surface of silken tofu can be achieved if GdL is added in the form of a solution with a ratio of 1:10 GdL to water. To obtain silken tofu with good firmness and breaking strength we recommend stirring the solution for 10 - 30 minutes. During this time, GdL slowly hydrolyses into gluconic acid and progressively lowers the pH. If not enough time is given for GdL to dissolve properly or if the solution is stirred for too long, most of the GdL is already transformed into gluconic acid, which significantly reduces the hardness of silken tofu. To enhance the firmness and the breaking strength even further, consider a combination of GdL and calcium sulphate in a ratio of 1:1.

In combination with soy proteins GdL provides very good water-binding capacity and thus reduces whey separation. GdL also enables in-place coagulation, i.e. coagulation, storage and transport in individual packaging containers – yet another benefit for producers.

Jungbunzlauer is happy to provide additional information about Glucono-delta-Lactone in silken tofu on request.

References

- [1] K. C. Chang: Chemistry and Technology of Tofu Making. In Y. H. Hui: Handbook of Food Science, Technology and Engineering (4th edition). Boca Raton: CRC Press, p. 171-4–171-20, 2006.
- [2] K. Liu: Soybeans – Chemistry, Technology and Utilization (1st edition). Dordrecht: Springer Science and Business Media, 1997.
- [3] A. Dey, R. Prasad, S. Kaur, J. Singh, M. D. Luwang: Tofu: technological and nutritional potential. Indian Food Industry Mag, Vol. 36, No 3, p. 8-24, 2017.
- [4] Y. Cheng, N. Shimizu, T. Kimura: The viscoelastic properties of soybean curd (tofu) as affected by soymilk concentration and type of coagulant. International Journal of Food Science and Technology, Vol. 40, p. 385–390, 2005.
- [5] T. Metzger: Angewandte Rheologie (1st edition). Graz: Anton Paar GmbH, 2014.
- [6] S. K. C. Chang: Soymilk and Tofu Manufacturing. In Y. H. Hui: Handbook of Food Products Manufacturing. New Jersey, John Wiley & Sons Inc., p. 1063-1091, 2007.

About Jungbunzlauer

Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Due to continuous investments, state-of-the-art manufacturing processes and comprehensive quality management, we are able to assure outstanding product quality. Our mission "From nature to ingredients®" commits us to the protection of people and their environment.

Jungbunzlauer offers different granulations of Glucono-delta-Lactone for food applications as well as pharmaceutical and personal care products.

The Authors

Johanna Kurrat – Senior Project Manager Application Technology, Jungbunzlauer Ladenburg GmbH
johanna.kurrat@jungbunzlauer.com

Lena Perkins – Technical Service Manager, Jungbunzlauer International AG
lena.perkins@jungbunzlauer.com

Discover more on
www.jungbunzlauer.com

