# New techniques induced from traditional soybean products and new technology of soybean process

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## Soybean Consumption for Food, Feed, & Crush :World


This figure shows soybean consumption for food, feed, and crush for oil in the world. Crush occupies 80% of all soybean and reaches to 2 hundred million tons in 2007.

This crushed soybean is defatted and becomes soybean meal and oil.

## World Oil; Soybean Statistics and Graphics：WORLD


Soybean oil increased with a million per year from 1985 to 2005 and reached to 30 million tons.

From 2005, Industrial consumption (red line) increases for bio diesel oil.

## Soybean meal consumption for Industry, Food, & Feed :WORLD

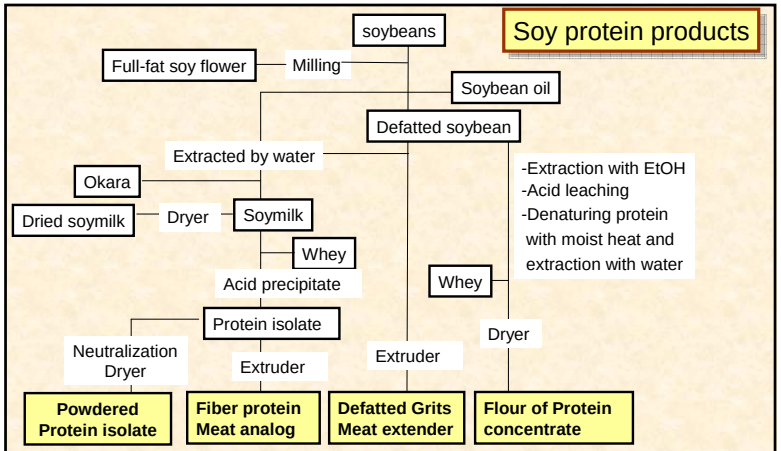

Now, I'll talking here about soybean meal in the world. Almost meal is consumed for feed, and the consumption reaches to 160 million tons in 2007.

A few percents are used for food in the world. We can't see the line.

## Soybean meal consumption for Industry, Food, & Feed :JAPAN


But in Japan, 13% of meal has been used for industry and food.
Industry uses for soy source are 300 thousands tons and
food as protein extender are 200 thousands tons in 2007.

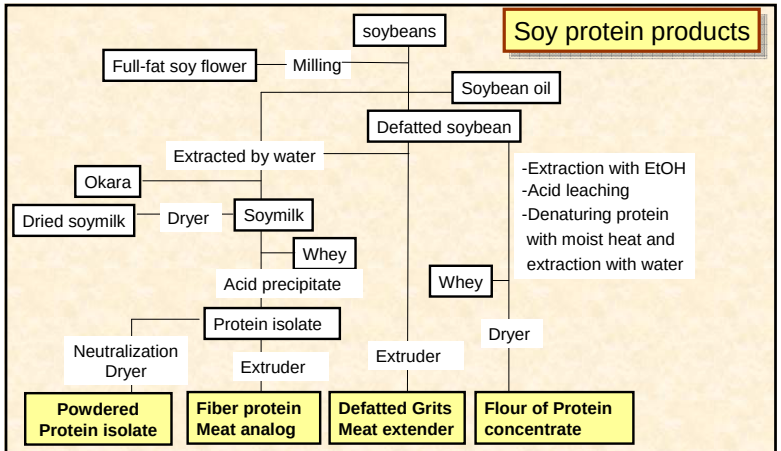
## Soy protein products




This figure shows a schematic diagram of soy protein products from soybean. I'll be mainly talking about yellow boxes; protein isolate, meat analog, meat extender, and protein concentrate.

Protein isolate is produced from soymilk of defatted soybean by acid precipitation. One is neutralized, dried and becomes Powdered protein isolate. Another is extruded and becomes Fiber protein meat analog.

## Soy protein products




On the other hand, defatted soybean is extruded and becomes defatted grits meet extender.

Defatted soybean furthermore is leached with ethanol, acid, or moist heat and extraction with water and then dried. These are Flour of protein concentrates.

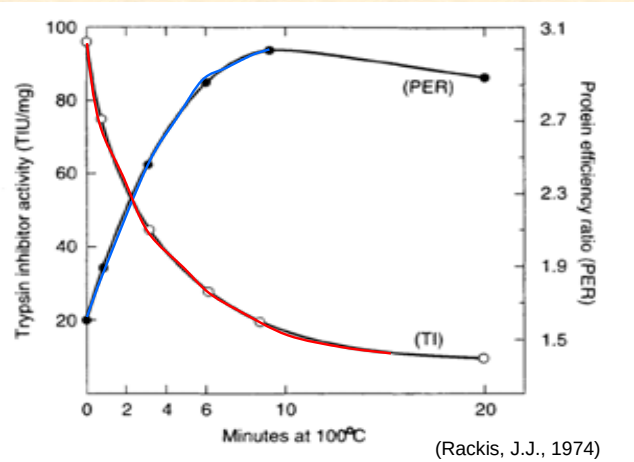
These soy protein products are now using for meat products, noodle and pasta, soups, and daily dishes.

## Typical Compositions (%) of Soy Protein Products

| Constituent | Defatted Flours and Grits | | Protein Concentrates | | Protein Isolates | |
|---|---|---|---|---|---|---|
| | as is | mfb[a] | as is | mfb[a] | as is | mfb[a] |
| Crude protein (N x 6.25) | 52–54 | 56–59 | 62–69 | 65–72 | 86–87 | 90–92 |
| Crude free lipid (pet. ether) | 0.5–1.0 | 0.5–1.1 | 0.5–1.0 | 0.5–1.0 | 0.5–1.0 | 0.5–1.0 |
| Crude Fiber | 2.5–3.5 | 2.7–3.8 | 3.4–4.8 | 3.5–5.0 | 0.1–0.2 | 0.1–0.2 |
| Ash | 5.0–6.0 | 5.4–6.5 | 3.8–6.2 | 4.0–6.5 | 3.8–4.8 | 4.0–5.0 |
| Moisture | 6–8 | 0 | 4–6 | 0 | 4–6 | 0 |
| Carbohydrates (by difference) | 30–32 | 32–34 | 19–21 | 20–22 | 3–4 | 3–4 |

[a]mfb: moisture-free basis.
*Source: Soy Protein Products*, Soy Protein Council, Washington, DC.

This table shows typical compositions of soy protein products.
Protein content of defatted flours and grits is 50 to 60 %,
that of protein concentrates is 60 to 70%, and that of protein isolate is 80 to 90%.




(Rackis, J.J., 1974)

The properties of soybean meal are changed by heat treatment time on defatting process. Trypsin inhibitor activity decreases with heating time,and protein efficiency ratio increases.

Processing and Nutritional Parameters of Heat-Treated Soy Flours

| Heat,[a] min | NSI[b] | TI, TIU/mg[c] | PER[d] | Pancreas wt, g/100 g body wt |
|---|---|---|---|---|
| 0 | 97.2 | 96.9 | 1.13 | 0.68 |
| 1 | 78.2 | 74.9 | 1.35 | 0.58 |
| 3 | 69.6 | 45.0 | 1.75 | 0.51 |
| 6 | 56.5 | 28.0 | 2.07 | 0.52 |
| 9 | 51.3 | 20.5 | 2.19 | 0.48 |
| 20 | 37.9 | 10.1 | 2.08 | 0.49 |
| 30 | 28.2 | 8.0 | | |

[a]Live steam at 100°C.
[b]NSI = nitrogen solubility index
[c]TI = trypsin inhibitor; TIU = trypsin inhibitor units
[d]Protein efficiency ratio, corrected on a basis of PER = 2.5 for casein

(Fulmer, 1989)

On the other hand, nitrogen solubility index, that is NSI, decreased with heating time.

## PDI:

The Protein Dispersibility Index ( AOCS Official Method Ba-10-65, 1993) "rapid stir" method uses a blender to disperse the sample.

## NSI:

The Nitrogen Solubility Index (NSI; AOCS Official Method Ba 11-65, 1993) "slow stir" method uses a laboratory stirrer.

Protein dispersibility index, PDI is related to NSI like this equation.

$$PDI = 1.07(NSI) + 1$$

Applications of Defatted Soy Products in Foods is limited by PDI

| PDIa | Application |
|---|---|
| 90+ | White breat–bleaching agent |
| | Fermentation |
| | Soy protein isolates, fibers |
| 60–75 | Controlled fat and water absorption |
| | Doughnut mixes |
| | Bakery mixes |
| | Pastas |
| | Baby foods |
| | Meat products |
| | Breakfast cereals |
| | Soy protein concentrates |

| PDIa | Application |
|---|---|
| 30–45 | Meat products |
| | Bakery mixes |
| | Nutrition, fat and water absorption, emulsification |
| 10–25 | Baby foods |
| | Protein beverages |
| | Comminuted meat products |
| | Soups, sauces and gravies |
| | Hydrolyzed vegetable proteins |
| Soy grits | Nutrition, meat extender |
| | Patties, meatballs and loaves, chili, sloppy joes |
| | Soups, sauces and gravies |

[a]Protein Dispersibility Index is a standard AOCS method (Ba 10-65) for measuring the amount of heat treatment used in the processing of soybean meal products. (Fulmer, 1989)

These soybean meals are defatted by solvent, mainly hexane.

## Screw pressing and extruding-expelling (EE) process for defatting

extruding-expelling instrument


Today, screw pressing and extruding-expelling (EE) process of soybeans is paid attention as the alternatives to hexane-based extraction.

Advantages of EE technology include process simplicity, low capital investment, and no need for organic solvents.

## Screw pressing and extruding-expelling (EE) process for defatting

extruding-expelling instrument


These processes leave 7–8% residual oil contents.

The enzyme-assisted aqueous extraction processing can extract 88–90% of the oil from EE flakes into the aqueous media (Lamsal and Johnson, 2007).

Another method for defatting and protein isolate

1. Make raw soymilk at pH 9
2. Centrifugation →→ float (oil)
3. Adjusted at pH4.5 →→ precipitated protein (protein isolate)

This technique is induced from the traditional method of soymilk. We can get soybean cream and protein isolate without organic solvent.

## Soy Protein Concentrates

Soy protein concentrate is made by these treatments. Defatted soy flour have strong flavor compounds and flatulence sugars; therefore extraction with aqueous ethanol was developed.

Acid leaching is also done to remove sugar, and moist heat and extraction with water improves protein efficiency ratio (PER).

* Extraction of meal with aqueous 20 to 80 % ethyl alcohol
* Acid leaching of meal or flour at pH 4.5
* Denaturing the protein with moist heat and extraction with water

## Approximate Composition of Soy Protein Concentrates Made by Three Extraction Processes

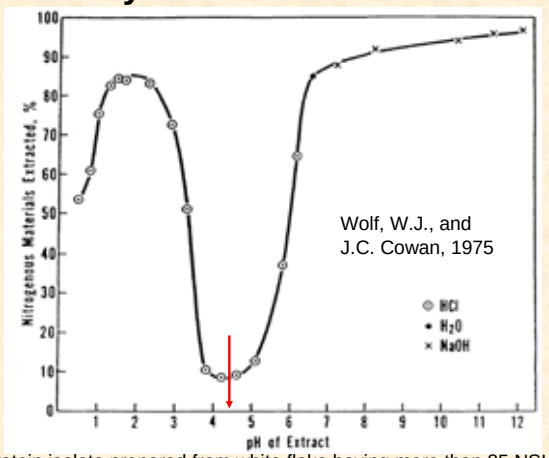
| Component | Alcohol process[b] | Acid process[c] | Hot-water process[b] |
|---|---|---|---|
| Protein (N x 6.25)[d] | 71 | 70 | 72 |
| Protein | 67 | 66 | 68 |
| Moisture | 6.0 | 6.0 | 5.0 |
| Fat | 0.3 | 0.3 | 0.1 |
| Crude fiber | 3.5 | 3.4 | 3.8 |
| Ash | 5.6 | 4.8 | 3.0 |
| Carbohydrate[e] | 17.6 | 19.5 | 20.1 |

[a]Data expressed as percentages.
[b]A.E. Staley Mfg. Co., Decatur, IL.
[c]Griffith Laboratories (Chicago, IL) Technical Data Sheet.
[d]Dry solid basis; all other data expressed on an "as-is" basis.
[e]Percentage by difference.

(Campbell, 1985)

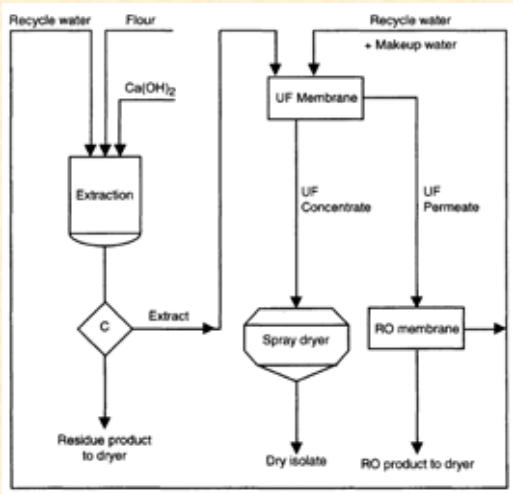
Defatted soybean meal contains 30% carbohydrate, and that of soy protein concentrate decreased below 20%.

## Soy Protein Isolate




Wolf, W.J., and J.C. Cowan, 1975

Soy protein isolate prepared from white flake having more than 85 NSI by using solubility properties at pH like this figure.
SPI is precipitates at pH 4.5 from white flake solution or soymilk.

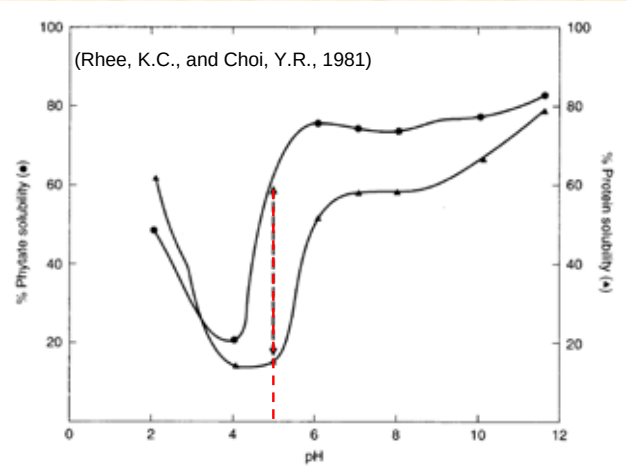



Simplified flow diagram for soybean protein isolation with UF and RO membranes.

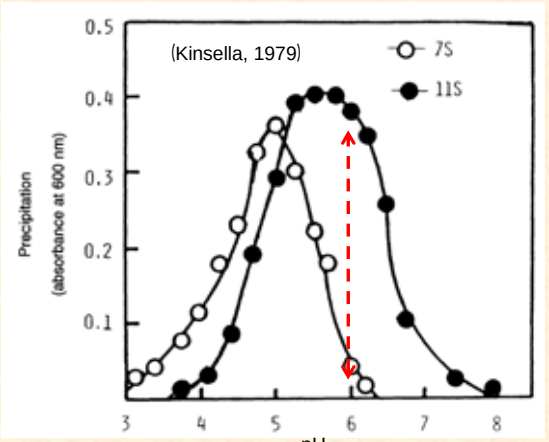
(Lawhorn, *e t al.*, 1981)

SPI without acid precipitation is developed by using UF and RO membranes like this diagram.

Effects of pH on solubility of protein and phytate in defatted flour.

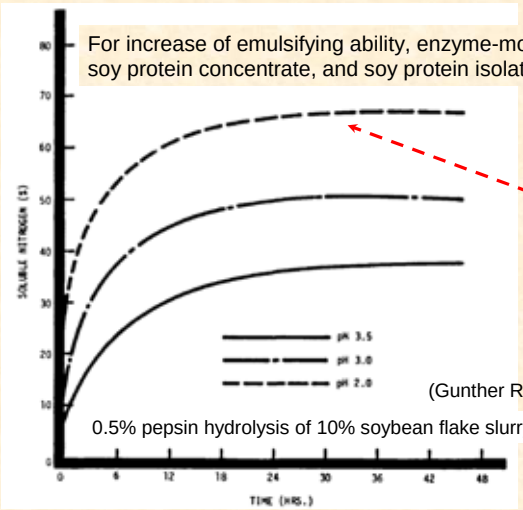



SPI with low pytate is also developed by using pH 5 precipitation in solubility difference of them like this figure.




SPI with rich 11S globulin precipitates at pH 6 and low temperature. Soluble residue contains rich 7S globulin. SPI with rich 7S has higher emulsifying ability. SPI made from EE meals had higher concentration of glycinin (Wang *et al.*, 2004).

For increase of emulsifying ability, enzyme-modified soy meal, soy protein concentrate, and soy protein isolate are prepared.




In soy meal like this figure, soluble peptides increased by pepsin hydrolysis at pH 2.0.

**Table 4—Foaming characteristics of soy protein hydrolysates and their unhydrolyzed controls[a]**

| | FC | $V_{max}$ | $V_i$ | K |
|---|---|---|---|---|
| HESF | | | | |
| Control | 0.79a | 27a | 7.31a | 0.009a |
| 2% DH | 0.95a | 31a | 10.14b | 0.016b |
| 4% DH | 1.03a | 28a | 10.53b | 0.016b |
| EESF | | | | |
| Control | 1.40a | 21a | 9.95a | 0.037a |
| 2% DH | 1.58a | 34b | 18.31b | 0.033a |
| 4% DH | 0.92b | 15c | 4.38c | 0.011b |
| SPC | | | | |
| Control | 0.75a | 26a | 6.49a | 0.008a |
| 2% DH | 0.33b | 13b | 1.52b | 0.119b |
| 4% DH | 0.47c | 13b | 2.32b | 0.187b |
| SPI | | | | |
| Control | 0.26a | 13a | 1.26a | 0.074a |
| 2% DH | 0.75b | 45b | 10.45b | 0.036b |
| 4% DH | 0.96c | 30c | 9.84b | 0.069a |

[a]Means in the same column followed by different letters are significant different at $P < 0.05$. DH =degree of hydrolysis; EESF =extruded-expelled soy flour; FC =foaming capacity; HESF =hexane-extracted soy flour; K =the specific rate constant for liquid drainage; SPC =soy protein concentrate; SPI =soy protein isolate; $V_i$ =the rate of incorporated volume; $V_{max}$ =an indicator of foam density.

S. Jung *et al.*, 2005

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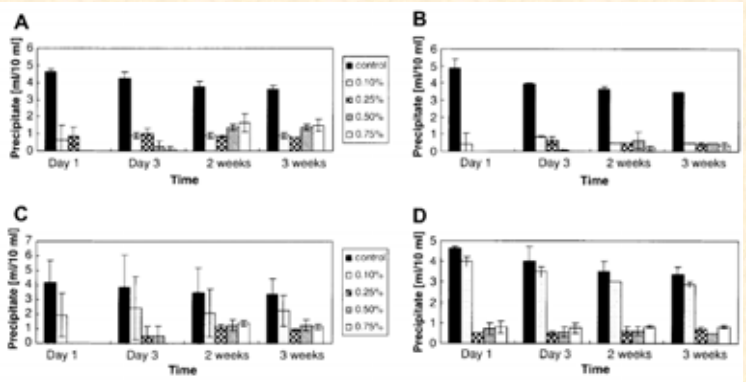
S. Jung *et al.*, 2005

The 2% hydrolysate of extruded-expelled soy flour shows higher forming capacity and form density. This new product, EESF contains few percents oil. It is expected as a new material for emulsifying.

## Pectin stabilization of soy protein isolates at low pH

M. Lam *et al*., Food Res. Int., 40, 101-110 (2007).




Sedimentation of SPI /pectin mixtures at pH 3.8 as a function of storage time at 4**℃**. Figures indicate the changes in sedimentation with pectin concentration (0 - 0.75%) for four pectin types: DE 71.4(A); DE 68.6(B); DE 59.6(C); DE 32.6(D). Measurements are the average of duplicate experiment (bars are standard error of measurement).

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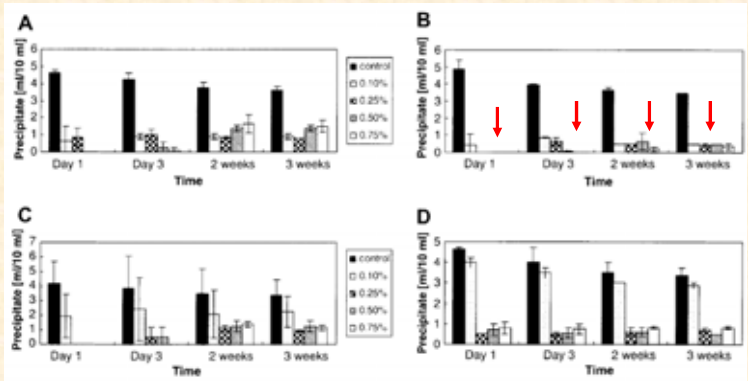
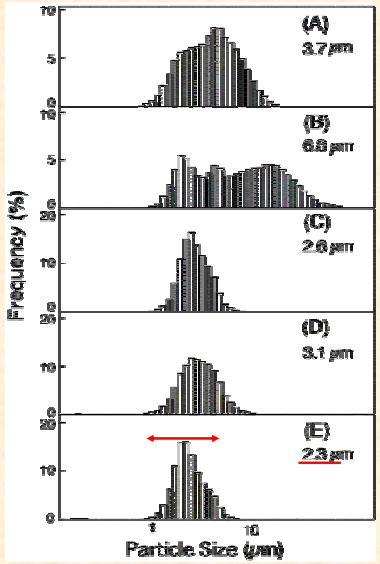



Protein solubility at low pH is important in food. SPI precipitates near pH 4, but did not precipitate by the addition of esterified pectin like this figure B.

## Particle size distributions of emulsions from glycinin samples

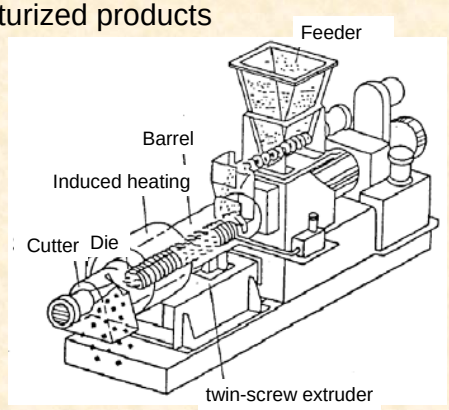



(**A**);11S
(**B**);group I-glycinin
(**C**); group II-glycinin
(**D**); A3B4-glycinin
(**E**);A5A4B3-glycinin

(Mruyama *et al.*, 2004)

Glycinin soy proteins is able to classified 4 groups (B to E) from 5 subunits. Emulsion stability can be show by the width and average size of particle size distribution. The distribution pattern of A5A4B3-glycinin (E) has a narrow width and smallest average size. This subunit has the best emulsion stability. This shows that soybean variety is important in emulsifying ability.

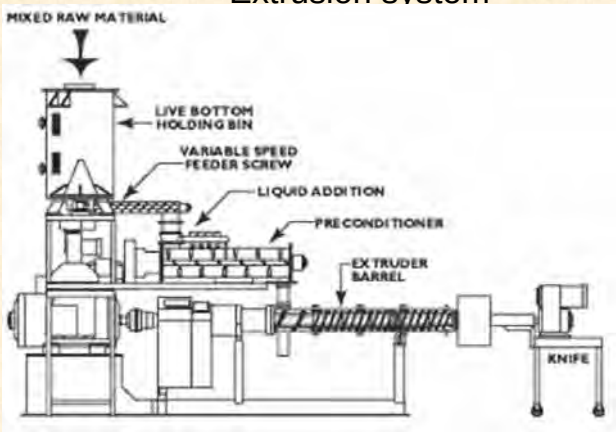
## Extruder-texturized products




This machine is Twin-screw type extruder. The soy flours, concentrates, and isolates are extruded and change to texturized products having multi-laminate palisade layers in a short time.

Extrusion texturization has the advantages of texturize lower-cost ingredients.

## Extrusion system




This figure shows extrusion system of one screw type extruder.

This is one screw type extruder, an industrial model.

**Twin-screw type extruder**

SUEHIRO EA-300

This is two screws type extruder, an industrial model.
It is able to treat ingredients of 300 kg/h.

Twin-screw type extruder

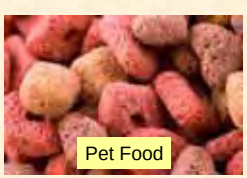

This two screws type extruder is a model for research.
It is able to treat ingredients of 20 kg/h.

These photos are Extruder-Texturized Products

Texturized soy meat

Soy grits

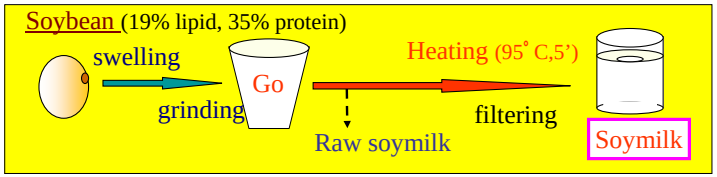
Meat extenders




These photos are Marketing foods of Extruder-Texturized Products.

## Soymilk and Tofu (traditional products)

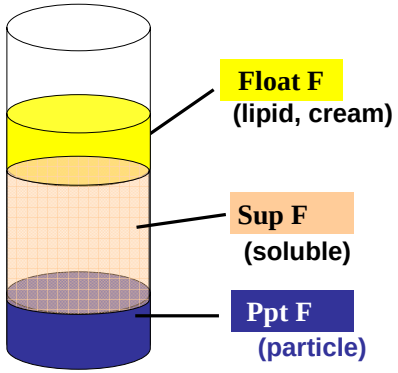
**Soymilk formation**



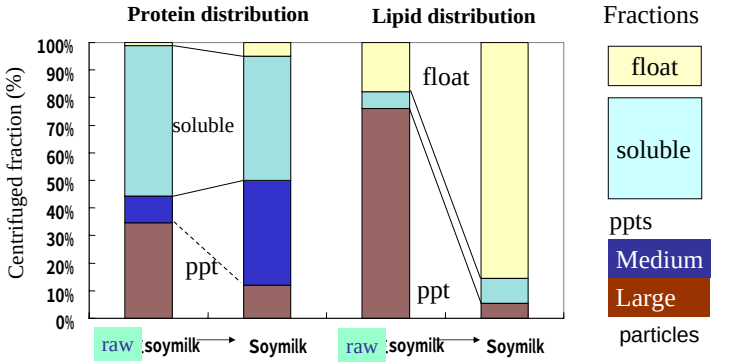

The Soymilk and tofu-curd processing is a traditional proceeding of soybean in Asian countries.
Soymilk is a stable turbid colloidal liquid containing protein, lipid and sugar as similar to cow's milk. The stable colloidal liquid is made by grinding, heating, and filtration of swelled soybean.

At first, we tried to elucidate the components of these colloids.

Soymilk was centrifuged by ultracentrifugation.

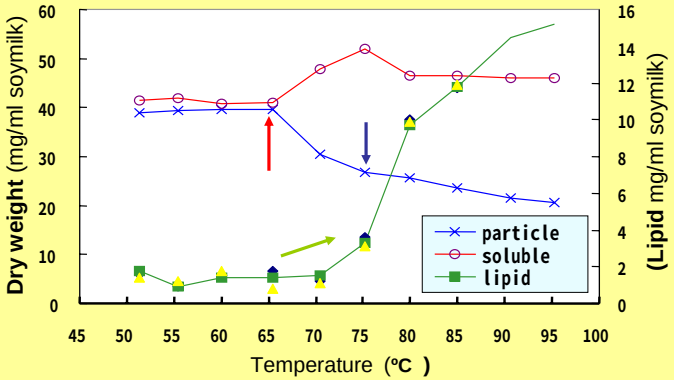



## Raw soymilk changes to soymilk by heating



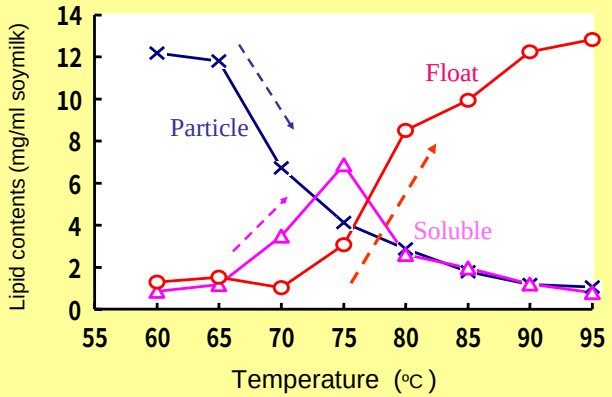

In protein distribution, large particle fraction decreased and medium particle fraction increased by heating.
In lipid distribution, large particles decreased and float F increased by heating.
These changes were then observed at elevated temperature.

## Change of soymilk fractions by heating



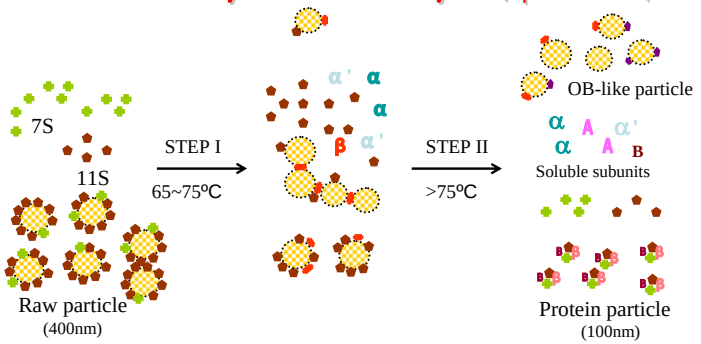

Raw particles decomposed from above 65ºC , and lipid F was floated gradually.
Particle F changed above 75 ºC from large to medium particles.

## Change of lipid content in soymilk fractions by heating




Lipid in particles decreased above 65ºC , and that in soluble F increased up to 75ºC . Above 75ºC , lipid shifted into float F.

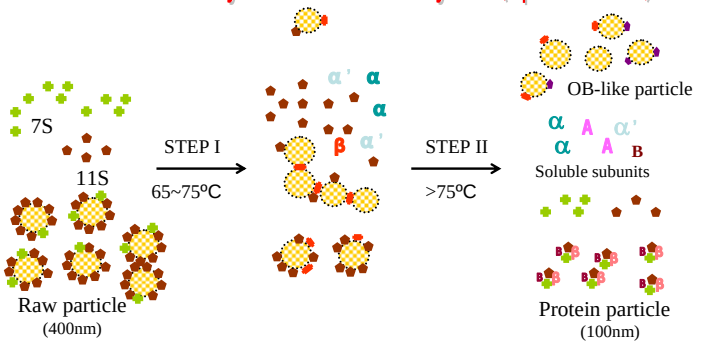
## Formation of soymilk from raw soymilk (speculation)




Raw soymilk — Soymilk

From talking results, we proposed new mechanism of soymilk formation. Proteins exist in conjugated form with lipids globules in raw soymilk, and then by heating, 7S and 11S globulins are released in turn at 75 and above 80 ºC from lipid globules, respectively.

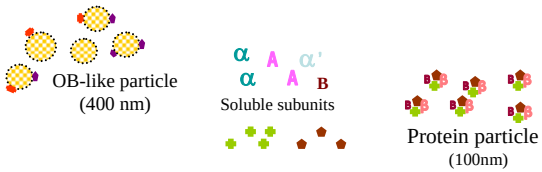
## Formation of soymilk from raw soymilk (speculation)




Raw soymilk — Soymilk

The protein particles having about 100nm in diameter are formed from these subunits. Lipid globule is released by heating and is same as oil body.

## Components of Soymilk

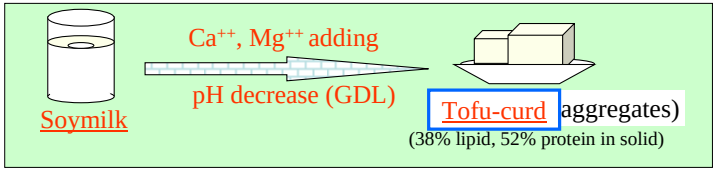



Soymilk is as a stable colloidal solution consist of protein particles and oil body. These particles having about 100 and 400nm in diameter are not precipitated.

The making method of soymilk is an important technique for making a oil body and a stable colloidal protein and can be applied to other processing.

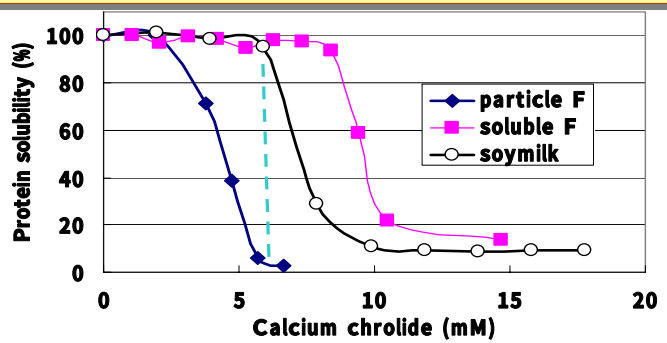
## Soymilk and Tofu (traditional products)

Tofu formation




Soymilk consists of particle and soluble proteins, oil body, and so on.
The main components are 50% protein and 35% lipid in dry matter base.
Tofu-curd is made from the soymilk by addition of Ca or Mg ions and GDL.
The lipid in the tofu-curd is very stable against ooze and oxidation by cooking and storing.
Therefore, the tofu-curd is an important food source for a stable lipid supply.
We made clear the mechanism of the curd formation.
This mechanism will propose a stable fixation technique of lipid with protein.

**The first stage of tofu formation is the addition of $Ca^{++}$, Soluble and particulate proteins separated from soymilk were used.**

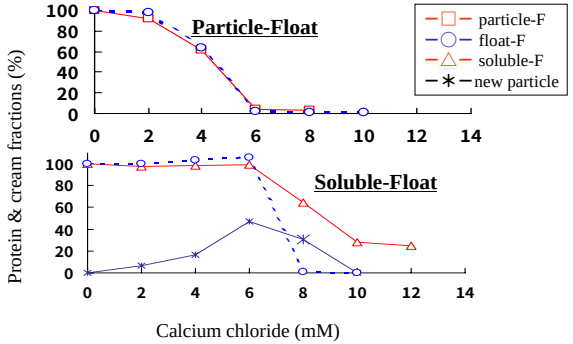



In the addition of $CaCl_2$, the protein solubility of particulate fraction decreased at lower calcium concentration than that of soluble F.

The protein decrease in soymilk occurred after the precipitation of particulate F.

Why does not the particulate F in soymilk precipitate at the precipitation point of separated particle? Separated fractions didn't contain float fraction.

**Change in protein and float fractions of these mixtures was observed.**



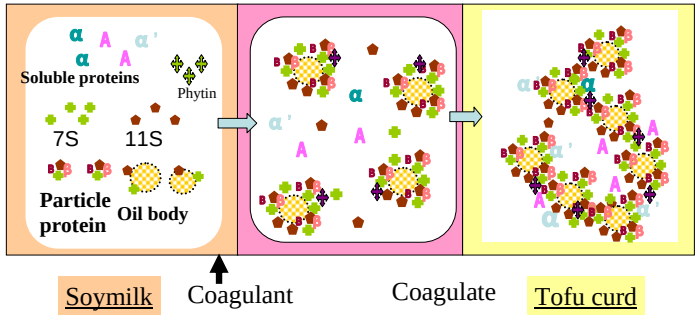

Calcium chloride (mM)

In mixed solution of particulate and float fractions, the decrease of these fractions took place at same Ca concentration.

Then, in the mixed solution of lipid and soluble fractions, lipid fraction decreased after new protein particles were formed from soluble proteins by the addition of $CaCl_2$ .

These results indicate that the decrease of float fraction was induced by binding of particulate fraction.

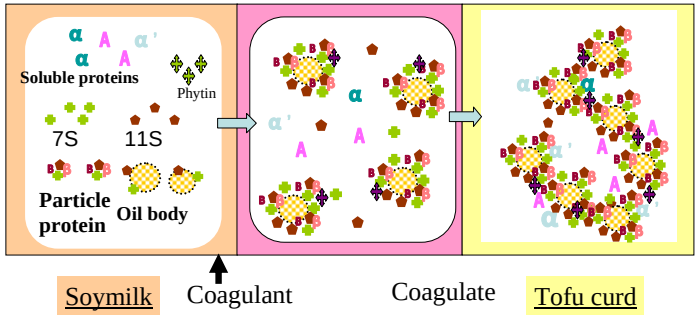
## Tofu curd formation from soymilk (by T.Ono)




The new idea of tofu curd formation has been introduced from the talking results.

Soymilk looks like bovine milk containing micellar protein particles and fat globules. Soymilk also contains particle proteins and oil body.

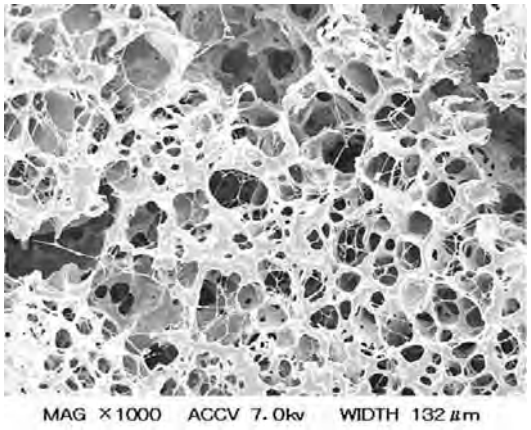
## Tofu curd formation from soymilk (by T.Ono)




When coagulant is added,
Particle proteins adhere to oil body surface. These oil bodies are able to combine each others.

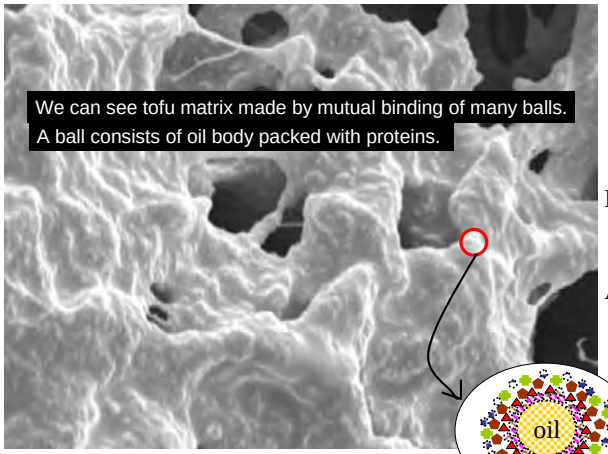
Then, the protein-packed oil bodies form tofu curd containing water.

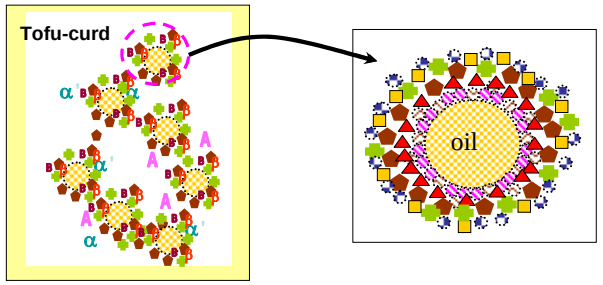
## Scanning electron micrograph of tofu at x1000




Tofu has many holes, which is fulled with water. We can see tofu network.

## Scanning electron micrograph of tofu at x10,000



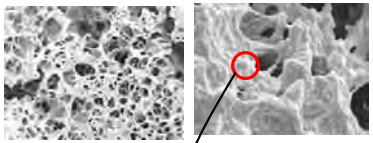




**In tofu-curd, Oil body is packed with soy-proteins. The oil is extremely stable against ooze and oxidation.**

## Oil in tofu ?・・・・・

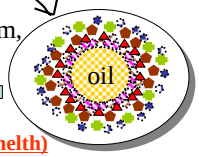

**It's very stable.**

**SEM photographs of tofu**



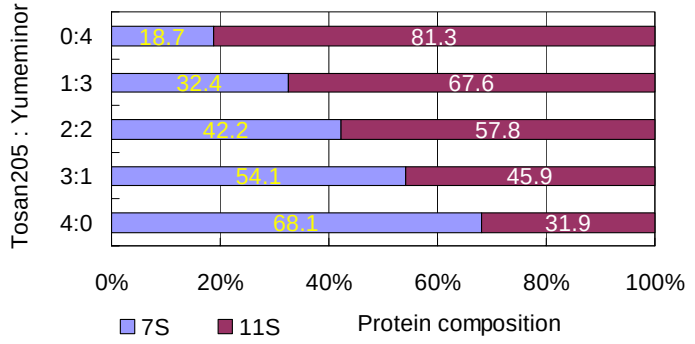

Oil is packed with proteins.

We applied this mechanism, to commercial product




**DHA (unstable but good for helth) was processed to a stable drink.**

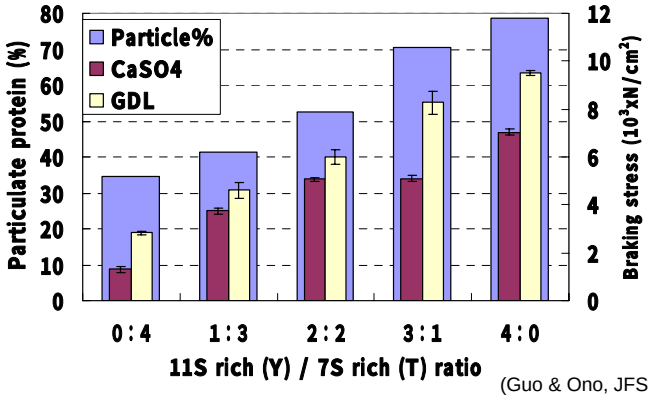
The 11S/7S ratio of Protein varies in the soybeans varieties.
We made soymilks of various 11S/7S ratio from mixed soybean,
(Tosan205 : Yumeminori = 0:4 to 4:0)
11S/7S ratios of these soymilks were analyzed by SDS-PAGE.




The tofu in next experiment was made from these mixed soybean soymilks.

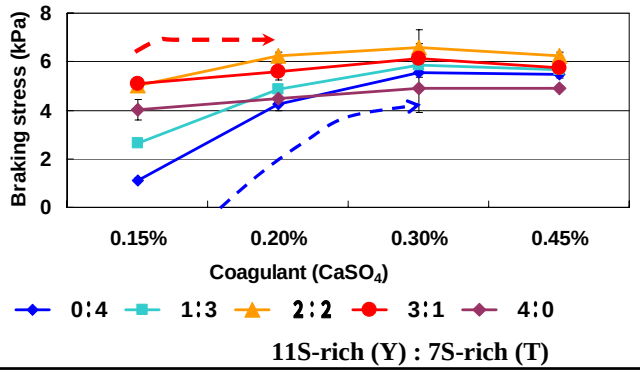
The increase of 11S/7S protein ratio in soymilk introduced the increase of particulate protein,

and then introduced the increase of braking stress of $CaSO_4$- and GDL- tofu made by these soymilks.

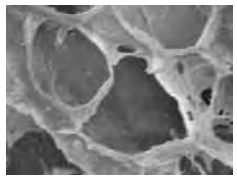



(Guo & Ono, JFS 2005)

The braking stress (BS) of tofu varies in coagulant concentration (CCn).
Therefore, BS of various 11S/7S-tofus was measured against CCn.
The increase in the 11S content induced in quick attainment of
the maximum braking stress at low CCn.
The values in 7S rich is like this, and
The values in 11S rich is like this.

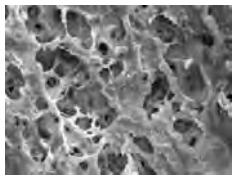



Low — Coagulant ($CaSO_4$) → High



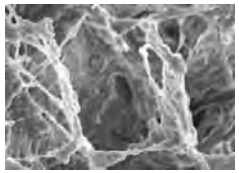

At low coagulant,
tofu shows thin flat wall &
big cell-like network

7S



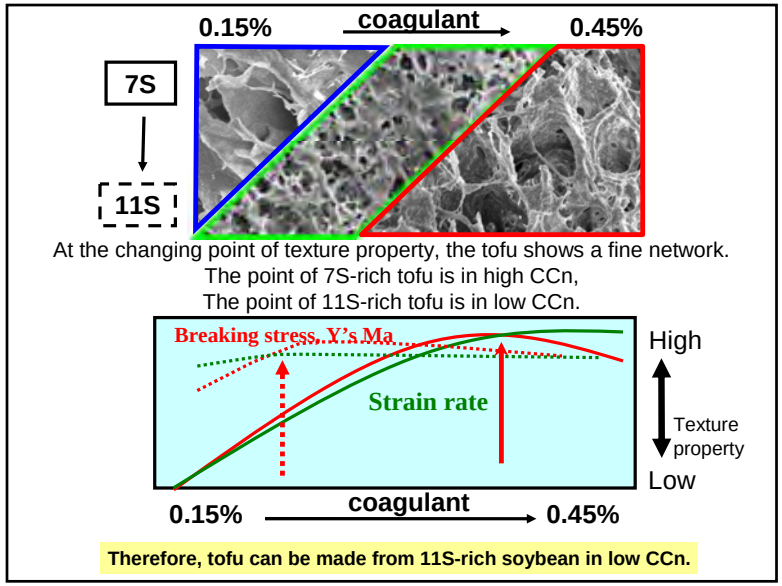

At just CCn,
tofu shows a fine
uniform network.

The just CCn is
low in 11S rich tofu,
& high in 7S rich tofu.




11S

At too much coagulant, tofu
shows large non-uniform
cell-like network & non-flat wall




## Conclusion

**From Hexane extracted soybean meal**,

- Defatted flour & Grits, protein concentrate, protein isolate
- New techniques
  - 7S, 11S-rich proteins, low phytate protein, Acidic stable protein
  - Functional peptides from soybean protein
  - Various extruder products by new machine
- Extruded expelled soy products have new function without organic solvent.

**Traditional products, soymilk & tofu**

From soymilk

- We can get oil as oil body, which is stable against oxidation.
  of course, SPI, too.
- Colloidal stabilization of protein against heated aggregation.

From tofu

- Lipid stabilization with protein against ooze and oxidation
- Curd making technique from lipid and protein