INTSOY Seminar 2011
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AKICORP
PROJECT INTEGRATORS
FOOD, ENERGY & WASTE

Introduction

Production of Soy Milk in factories is a process that involves several operations. There are many routes to obtain Soy Milk, out of which we could mention

- Direct mixing of ingredients like SPI (Soy Protein Isolates or flours) with water, oils, emulsifiers, sugars, stabilizers, etc.
- As simple as Soy Milk Powder and water reconstituted to its original condition
- And then some more which are the result in one way or another of water extraction from the beans.

The process of extracting-producing Soy Milk from beans and water follows different philosophies and techniques. Very well known companies have different approaches and use different equipment and process parameters to perform this task. We will not evaluate the different technologies in this experience; we will simply produce Soy Milk using unit operations that will ultimately yield MILK.

Objective

1. Observation of the simple soaking process of Soy Beans and understanding how the swelling and absorption of water starts a process that will ultimately yield Soy Milk.
2. A firsthand experience will make terms like mass balance, yield, efficiency, protein content, moisture content and total solids, more familiar and understandable in the context of Soy Milk making.
3. It is intended that through the application of concepts like yield and mass balance together with costing elements, basic economics of Soy Milk production can be understood

Requirements

Regardless of the technology, recipe, equipment or procedures applied, it is common to all of the available processes, industrially applied to obtain Soy Milk that :

1. Soybeans are soaked in water
2. Soybeans are wet-ground
3. A slurry is formed
4. Milk is contained in the slurry
5. Solids-fibers are separated from liquid Milk
6. Trypsin Inhibitor enzymes and Lipoxygenase Oil oxidizing enzymes are deactivated
7. Milk is Heat treated also to kill bacteria and pathogens
8. Finally Milk and Okara are obtained as final product and by product

The following procedure will replicate what happens in Soy Milk factories and will help understand the mechanics of the production and what determines the economics of the process.

Note 0 Soybeans are normally expressed in a volumetric magnitude called bushel. One bushel

For this experience we will use

- A weighted amount of dry beans
- Water for soaking the beans
- A small boiler to produce steam /hot water
- A batch machine that comprises
    - Grinding (mixing/emulsifying/infusing)
    - Heating
- A filter to separate fibers (Okara) from milk
- A balance to weigh ingredients
- Graduated containers to measure volumes
- Lab. Equipment to measure
    - Moisture in dry products like beans or Okara
    - Solids in liquid products like Milk
    - Protein content
    - Fats or Oils

Procedure

Weigh _________ grams. of dry soybeans

Weighted beans are poured into a graded flask

Measure dry volume in Lts.

Volume = _________ Lts.

So far we can calculate the bulk density of the dry beans.

ρ= density = mass/volume = bulk density

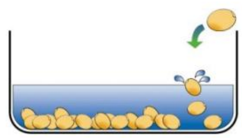
This is the weight of beans contained in a known volume

Show your result here $\frac{W}{V}$ = gr/Lt or kg/M3 **DRY**

This beans will continue with the process and will become part of a batch (one load) where we will make soymilk in a non continuous way. In consideration to the batch type of operation, time will not be part of any of our equations in production. The overall time counted from the moment the soaked beans are introduced until the milk is finally obtained and filtered will be considered the time during which one batch is processed.

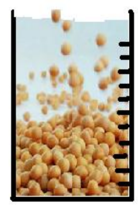
Repeat procedure after soaking the weighted beans in water

We will observe that beans grow in size, hence occupying more volume and they will also increase in weight as the absorbed water will be added to their mass. How much water is absorbed? depends on time of soaking, temperature, beans variety, time in storage, acidity of the water, oil content of the bean, type of drying applied to the bean and maybe some more. Soaking is a key process in making soy Milk and each company has a different philosophy



Drain and Weigh __________ grams. of wet soybeans

Weighted beans are poured into a graded flask



Measure Wet volume in Lts.

Volume = __________ Lts.

We can now calculate the bulk density of the Wet beans.

ρ = density = mass/volume = bulk density

This is the weight of beans contained in a known volume

Show your result here $\frac{W}{V}$ = gr/Lt or kg/M3 **WET**

Dairy and soy milk have a density of about 1.03 gr/cc

LAB INFORMATION

We get from lab analysis the following data from the **DRY BEANS** that we are using for this experiment. Every different lot of beans has different values and within the same lot, these values may change during the day.

Table 1 Obtained from LAB: for DRY BEANS Lot INTSOY 060811

SPEC	Typical in %	Obtained in %
Protein content	36.8	
Fat Content	17.5	
Moisture	13	
others		

Results obtained from lab are extensive to our sample and will remain constant during the soaking process expressed in absolute amounts. They will differ in percentages as the moisture content of the bean will be the only element to change.

Milk Production

Enough water will be added to all the soaked beans and together they will enter the process of Making Soy Milk as the only 2 ingredients

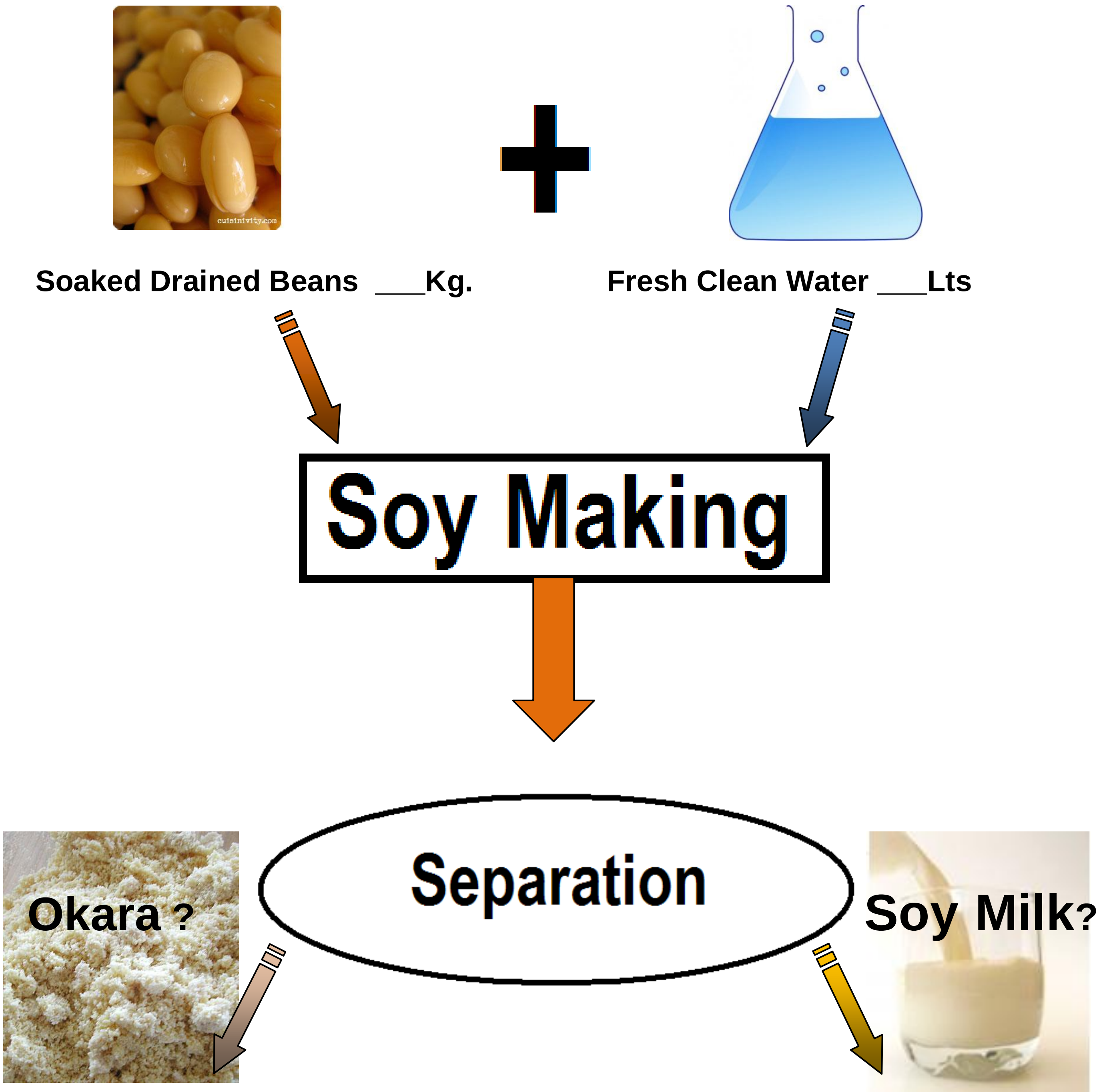


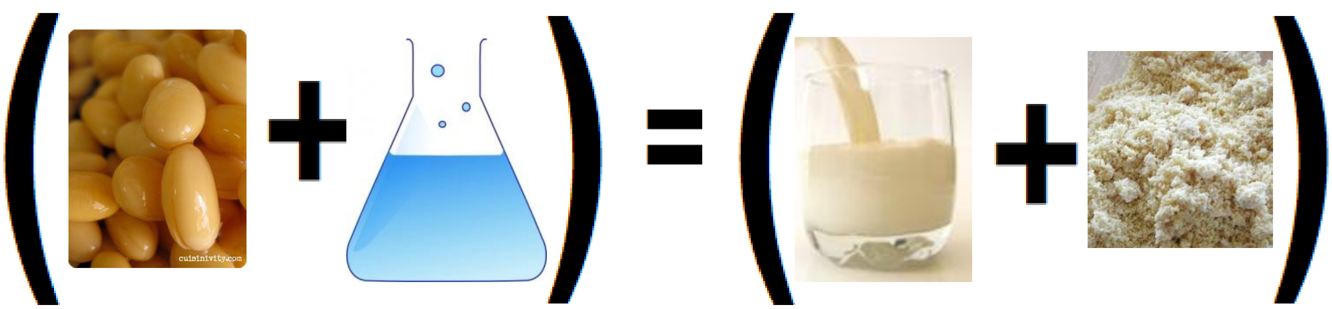
Table 2 Obtained from LAB: for SOY MILK INTSOMILK

SPEC	Typical in %	Obtained in %
Protein content	3.3	
Fat Content	2	
Total Solids	7	
others		

Fill in the values obtained in the lab from the analysis performed to the Soy Milk just made. With the right equations applied to the Mass Balance, we will be able to deduct the composition of the Okara.

Based on the simple principle of conservation of mass/matter we know that the total weight of the soaked beans plus the water added will be equal to the weight of the milk obtained plus the Okara resulting from the separation. The same applies to the amounts of proteins or fats due to the fact that no relevant chemical reactions occur I soymilk making other than slight neutralizations of fatty acids in minute quantities or deactivation of enzymes that loose original chemical structure (almost non measurable)

Expressed as an equation



Wet Beans **Water** **Milk** **Okara**

Identification of Variables in the equations

Name	Key	Units	Known or ?
Wet beans	**WB**	**Kg**	**Measure**
Water	**W**	**Lts or Kg***	**Measure**
Milk	**M**	**Lts. or Kg**	**Experiment Result**
Okara	**O**	**Kg**	**Experiment Result**
Protein in Beans	**pB**	**Kg**	**Lab result**
Protein in Milk	**pM**	**Kg**	**Lab result**
Protein in Okara	**pO**	**Kg**	**Calculate?**
Fat in Beans	**fB**	**Kg**	**Lab result**
Fat in Milk**	**fM**	**Kg**	**Lab result**
Fat in Okara	**fO**	**Kg**	**Calculate?**
Total Solids in Beans	**TSB**	**Kg**	**Lab result**
Total Solids in Milk	**TSM**		**Lab result**
Total Solids in Okara	**TSO**		**Calculate?**

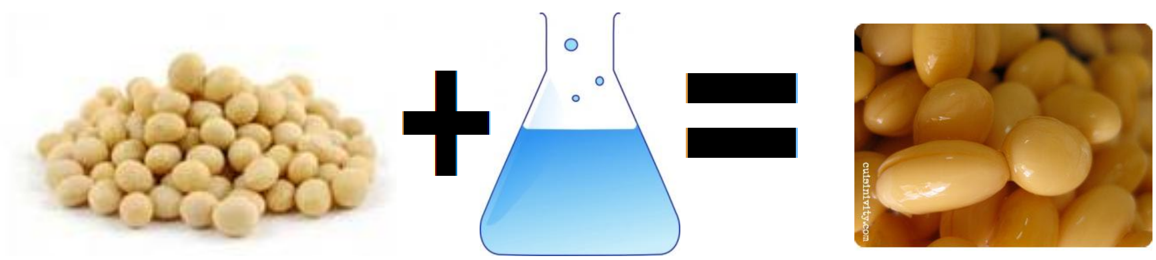
*Dairy and Soy Milk have a density of about 1.03gr/cc (makes it valid to say Kg or Lt)
** As Fat is emulsified in the milk the proportions obtained behave similarly to protein

Auxiliary Equations

Since

Protein in Wet Beans = Proteins in (milk + Okara)

Fat in Wet Beans = Fat in (milk + Okara)



Since to the Dry Beans we only add water for soaking
The composition (in weight) of the dry and wet beans are identical (except for the water content) Percentages are different

$$\begin{pmatrix} \text{Protein} \\ \text{Fats} \\ \text{Solids} \end{pmatrix}_{\text{weight}} = \begin{pmatrix} \text{Protein} \\ \text{Fats} \\ \text{Solids} \end{pmatrix}_{\text{weight}}$$

WB +W = M + O   **we can weigh or measure all these components**

___ + ___ = ___ + ___   verify this statement

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pB = pM + pO   **we know pB we obtain now pM from Lab results**

Then pB – pM = pO This equation gives us value for protein in Okara

___ _ ___ = ___   Show result for Protein in Okara

Similarly for fats and total solids

We do the same type of calculations that will help us learn the composition of resulting products and by products

fB = fM + fO we know fB we obtain now fM from Lab results

Then fB – fM = fO This equation gives us value for protein in Okara

___ _ ___ = ___ Show result for Fats in Okara

And again as Solids are only contain in Beans, not in water

TSB = TSM + TSO ⇨ TSO = TSB - TSM

TSO = ___ _ ___

With this last calculation we have the composition of all our products

Consideration
YIELD and EFFICIENCY

As we now know how much milk and what percentage of protein it contained, we can deduct the amount of beans used to produce said amount of milk is called YIELD.
Yield is the amount of milk produced with a certain amount of beans and expressed as

YIELD = $\text{Ч} = \frac{M}{B}$ Result in Lts of Milk / Kg. of Beans @ this protein concentration

We can deduct from this equation that just adding water to the milk we would obtain more milk, but at lower protein concentration!

Your value for Ч =

So ***YIELD*** is a ***value related to concentration*** and of course to the ***type of beans*** and the ***process applied***.

EFFICIENCY = $\eta = \frac{pM}{pB}$ Result in Total Protein in Milk / Total Protein in Beans in %

The amount of Protein contained in the beans is passed partially to the liquid after the infusion/emulsion/extraction process. Never, 100 % of the protein will be transferred to the SOYMILK and regardless how much water , what type of process or beans we use, or the protein content in % we want in the final Milk, ONLY part of the protein will be extracted. So dividing the total protein we find in the amount of milk made with a certain amount of beans, by the total protein content in the beans used to make this amount of milk will give us a fraction (0,1) meaning that its value will always be more than ZERO and less than ONE.

* There are certain processes, not very common, where the complete, dehulled, micronized, pretreated beans, are used completely in some sort of smoothie type milk, in which case, it could be said that extraction efficiency would be 100 %. Technically this is not true as it is not an extraction but rather a mix.

This EFFICIENCY determines how much bean we must use to make desired amount of bean at a set protein content. With all conditions being equal, this is , type of beans, amount of milk and protein content in the milk, the EFFICIENCY will determine if more or less beans are needed to make that milk.

EFFICIENCY is the best parameter to measure the quality of a process and both the philosophy and techniques applied in the extraction and production.

Your value for η =

If Beans Cost US$ 0.65/Kg.

Example

With an η **of 75 %** we should not need to make lab analysis to obtain the value of pM, and given a certain quality of beans which pB we know we could determine right away all the results of composition in the mass balance for a given SoyMilk process.

DATA from Table 1

Protein content	**36.8**
Fat Content	17.5
Moisture	13
others	

100 kg of beans at 36.8 % protein contain 100 *36.8% = 36.8 Kg of protein

If η **of 75 %,** then 75 % of 36.8 Kg will be in the milk = 36.8 * 75% = 27.6 Kg Protein

If we want to make a milk with 2 % Protein then 27.6 Kg will represent 2 in 100

Applying $\frac{2}{100} = \frac{27.6}{X}$ X = 1,380 Lts of Soy Milk

The cost of 100 Kg Soy Beans @ US$ 0.65 is US$ 65.00

With a process η of 75 % we managed to make 1,380 Lts of Soymilk with 2 % protein

2% protein means: One Cup (8 Fl ozs., or 240 ml) contains about 5 grams of protein

The Yield was for this example @ this conditions $\psi = \frac{M}{B} = \frac{\text{1,380 Lts.Milk}}{\text{100 Kg Beans}}$ = **13.8**

With a Yield of 13.8 Liters of Soymilk per Kg of Soybean
We conclude that we made with US$ 0.65, 13.8 Liters of Milk

For a 3.3 % Soymilk equivalent of Dairy Milk we could correct this number by a factor of 3.3/2 and the cost would be US$ 1.07 for the same 13.8 Liters @ 8 grams of Protein per cup.

Use the actual figures from this experience to plug into your formulas and obtain your own efficiencies, yield and costs.

Note 1

These are experimental results obtained from extraction parameters that are not ideal, under conditions not so easy to control. Very simple equipment and technologies result in efficiencies and yields far from ideal or optimum. Different process philosophies would determine different results.

Note 2

In real life, when we observe very sophisticated industrial processes down to the very simple, semi-industrial soy milk making equipment, we will discover differences of even 50 % in the extraction yields. Investigate factors that affect yield and which are more critical

Should you need to further discuss this experience please feel free to contact

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APENDIX

Agricultural commodities are normally expressed and negotiated in bushels. International trade is normally performed in metric tons.
A bushel is a volumetric measure and is equivalent to 1.2445 CuFt (cubic feet)
The following information illustrates how different crops, as a function of having different densities, represent different weights for one bushel.

Ref . http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4020

Weights per bushel*

- Alfalfa
  60 pounds per bushel
- Barley
  48 pounds per bushel
- Clover, Alsike
  60 pounds per bushel
- Clover, Crimson
  60 pounds per bushel
- Clover, Ladino
  60 pounds per bushel
- Clover, White
  60 pounds per bushel
- Clover, Red
  60 pounds per bushel
- Clover Sweet
  60 pounds per bushel
- Corn, shelled
  56 pounds per bushel
- Corn, ear
  70 pounds per bushel
- Cotton
  32 pounds per bushel
- Cowpeas
  60 pounds per bushel
- Flax
  60 pounds per bushel
- Grass, Brome (smooth)
  14 pounds per bushel
- Grass, Blue
  14 pounds per bushel
- Grass, Fescue (tall)
  14 pounds per bushel
- Grass, Orchard
  14 pounds per bushel
- Grass, Redtop
  14 pounds per bushel
- Grass, Timothy
  45 pounds per bushel
- Lespedeza
  40 to 50 pounds per bushel
- Millet
  50 pounds per bushel
- Oats
  32 pounds per bushel
- Rape
  60 pounds per bushel
- Rye
  56 pounds per bushel
- Sorghum, forage
  50 pounds per bushel
- Sorghum, grain
  56 pounds per bushel
- Soybeans
  60 pounds per bushel
- Sudan grass
  28 pounds per bushel
- Sunflower (oil type)
  24-32 pounds per bushel
- Trefoil, Birdsfoot
  60 pounds per bushel
- Vetch
  60 pounds per bushel
- Wheat
  60 pounds per bushel

*These values are all approximate as grain size, variety and moisture generate slight differences