

## S U M M A R Y

In this investigation, possibility of utilization of some important microorganisms in food industries i.e. Rhizopus oligosporus to improve the nutritional value by production some fermented foods from soybean and faba bean cotyledons which are called "Tempeh".

The objective of these studies included the following items:

- I. Effect of some pretreatments (soaking and germination) on the chemical composition and antinutritional components of soybean and faba bean cotyledons.
- II. Optimization of factors affecting fermentation in production of tempeh from soybean or faba bean cotyledons.
- III. Chemical properties and sensory evaluation of tempeh products and "Taameia".
- IV. Nutritional evaluation of tempeh products and "Taameia"

The obtained results could be summerized as follows:

1- Soybean seeds exhibited high crude protein, non protein nitrogen, ether extract and ash contents compared to faba bean seeds. Faba bean seeds exhibited high available carbohydrates and crude fiber contents compared to soybean seeds. Dehulling process resulted in increase

either crude protein or ether extract of soybean and faba bean cotyledons. Fiber content and available carbohydrates of soybean and faba bean were decreased by dehulling process. Soaking process led to increase moisture, crude protein and fiber contents and decrease non protein nitrogen, ether extract and ash contents of soybean cotyledons. This process led to increase moisture, crude fiber and available carbohydrates and decrease crude protein, non protein nitrogen and ether extract of faba bean cotyledons. Cooking process of dehulled soybean cotyledons (untreated, soaked and germinated) led to increase crude protein, ether extract and fiber contents and decrease non protein nitrogen, ash and available carbohydrates. This process led to increase ether extract and fiber contents and decrease crude protein, non protein nitrogen and available carbohydrates of dehulled faba bean cotyledons.

2- Soybean seeds exhibited high concentration of phytic acid and trypsin inhibitor activity (10.23 mg/g and 41.09 TIU/mg, respectively) than those of faba bean seeds (2.07 mg/g and 21.37 TIU/mg, respectively). However, faba bean seeds exhibited high concentration of total vicine (14.16 mg/g) than those of soybean seeds (5.15 mg/g). The dehulling process has no significant effect on phytic acid, trypsin inhibitor activity and total vicine of soybean.

This process led to increase trypsin inhibitor activity and total vicine only of faba bean. Soaking and germination processes led to significant decrease ( $P<0.05$ ) in phytic acid, trypsin inhibitor activity and total vicine of soybean and faba bean cotyledons. Cooking process of dehulled soybean and faba bean (untreated, soaked and germinated) led to more significant decrease in phytic acid, trypsin inhibitor activity and total vicine.

3- Chemical composition of tempeh products which were produced from (treated and untreated soybean and faba bean cotyledons) was determined. For soybean tempehs, moisture content, crude protein, non protein nitrogen, true protein, ether extract, ash content, crude fiber and available carbohydrates ranged as 52.01 and 64.79%, 43.16 and 55.54%, 0.19 and 0.93%, 40.98 and 49.99%, 15.14 and 29.58%, 3.44 and 5.74%, 3.85 and 7.23% and 11.75 and 22.33%, respectively. With respect to faba bean tempehs these components were in the range of 55.75 and 76.06%, 27.88 and 48.67%, 0.23 and 1.24%, 24.57 and 42.30%, 1.02 and 2.41%, 2.25 and 4.90%, 3.09 and 5.41% and 40.82 and 63.20%, respectively.

4- Total volatile nitrogen and ammonia of tempeh produced from soybean or faba bean cotyledons increased significantly ( $P<0.05$ ) with increasing incubation

temperatures and incubation periods generally or within the different treatments. Anyhow, it could be considered that the excellent tempeh is that produce of soybean or faba bean tempehs after soaking for 24 hr, incubated at 31°C for 36 hr incubation period. For these conditions total volatile nitrogen was 0.29 and 0.36% and ammonia was 0.25 and 0.29% in soybean and faba bean tempeh, respectively. These values are lesser than 0.40 and 0.30% which is the higher accepted values for total volatile nitrogen and ammonia, respectively by the panelists.

Statistical analysis showed that there are more or less significant differences in thiobarbituric acid of soybean or faba bean tempehs between the different treatments. Anyhow, general means of different treatments indicated that they are under the maximum accepted limit (7.71 mg malonaldehyde/kg).

5- pH value in soybean or faba bean tempehs increased significantly ( $P < 0.05$ ) with increasing incubation temperatures and incubation periods generally or within the different treatments.

6- Changes in antinutritional factors, phytic acid, trypsin inhibitor activity and total vicine, could be summerized as follows:

Phytic acid of soybean and faba bean tempehs decreased significantly ( $P<0.05$ ) from 7.44 and 1.20 mg/g to 6.12 and 0.96 mg/g with increasing incubation temperature from 25° to 31°C, respectively. It decreased significantly ( $P<0.05$ ) from 8.61 and 1.58 mg/g to 5.58 and 0.70 mg/g with increasing incubation period from 0 to 72 hr of soybean and faba bean tempehs, respectively. Increasing incubation temperature and incubation period within the different treatments led to significant decrease ( $P<0.05$ ) in phytic acid of soybean or faba bean tempehs. Phytic acid decreased significantly ( $P<0.05$ ) from 7.21 and 8.36 mg/g to 4.05 mg/g with increasing incubation temperature from 25° to 31°C and increasing incubation period from 0 to 36 hr of soybean tempeh produced from soybean soaked for 24 hr. The same trend was observed in the case of faba bean tempeh. This treatment was an optimum one to produce the excellent tempeh from soybean or faba bean.

Trypsin inhibitor activity decreased significantly ( $P<0.05$ ) from 17.30 and 8.48 TIU/mg to 9.99 and 5.69 TIU/mg with increasing incubation temperature from 25° to 31°C of soybean and faba bean tempehs, respectively. It decreased significantly ( $P<0.05$ ) from 25.63 and 13.71 TIU/mg to 8.50 and 4.12 TIU/mg with increasing incubation period from 0 to 72 hr of soybean and faba bean tempehs, respectively. Increasing incubation temperature and

incubation period within the different treatments led to significant decrease ( $P < 0.05$ ) in trypsin inhibitor activity of soybean or faba bean tempehs. Trypsin inhibitor activity decreased significantly ( $P < 0.05$ ) from 10.03 and 19.28 TIU/mg to 3.21 TIU/mg with increasing incubation temperature from 25° to 31°C and increasing incubation period from 0 to 36 hr, of soybean tempeh produced from soybean soaked for 24 hr, respectively. The same trend was observed in the case of faba bean tempeh. This treatment was an optimum one to produce the excellent tempeh from soybean or faba bean.

Total vicine content decreased significantly ( $P < 0.05$ ) from 2.30 and 6.60 mg/g to 2.03 and 5.60 mg/g with increasing incubation temperature from 25° to 31°C of soybean and faba bean tempehs, respectively. It decreased significantly ( $P < 0.05$ ) from 2.75 and 7.71 mg/g to 1.67 and 4.96 mg/g with increasing incubation period from 0 to 72 hr of soybean and faba bean tempehs, respectively. Increasing incubation temperature and period within the different treatments led to significant decrease ( $P < 0.05$ ) in total vicine content of soybean or faba bean tempehs. Total vicine content decreased significantly ( $P < 0.05$ ) from 1.73 and 2.01 mg/g to 1.34 mg/g with increasing incubation temperature from 25° to 31°C and increasing incubation period from 0 to 36 hr, of soybean tempeh produced from

soaking process for 24 hr, respectively. The same trend was observed in the case of faba bean tempeh. This treatment was an optimum one to produce the excellent tempeh from soybean or faba bean.

7- Results of chemical properties of tempeh produced from soybean and faba bean cotyledons as affected by mixing with green spices and frying compared with "Taameia" could be summarized as follows:

Fermentation process led to significant ( $P < 0.05$ ) increase crude protein and fiber contents and decrease ether extract, ash and available carbohydrates of either soybean or faba bean tempehs. Addition of green spices led to significant decrease ( $P < 0.05$ ) crude protein and ether extract of soybean tempeh from 49.04 and 24.00% to 40.56 and 20.13%, respectively. With respect to faba bean tempeh this decrease was from 36.12 and 1.39% to 30.28 and 1.20%, respectively. It led to significant increase ( $P < 0.05$ ) of ash, fiber and available carbohydrates of either soybean and faba bean tempehs except available carbohydrates of faba bean tempeh which was increased insignificantly ( $P > 0.05$ ). Frying process led to significant decrease ( $P < 0.05$ ) in all chemical components of either "Taameia", and all soybean and faba bean tempeh products.

8- Addition of green |spices to soybean and faba bean tempeh led to significant increase ( $P < 0.05$ ) in total volatile nitrogen and ammonia of these products. Thiobarbituric acid (TBA) decreased significantly ( $P < 0.05$ ) by adding green spices to tempeh produced from soybean or faba bean. Frying process led to significant decrease ( $P < 0.05$ ) in total volatile nitrogen, ammonia and pH value of "Taameia" and all tempeh products. Anyhow, it could be noticed that fried tempeh products contained higher amounts of total volatile nitrogen and ammonia compared to "Taameia" but still in the accepted range. Frying process led to significant increase ( $P < 0.05$ ) in TBA of "Taameia" and all tempeh products. Anyhow, in spite of TBA in fried tempeh products is significantly higher than TBA in "Taameia", it is still in accepted range.

9- Addition green spices to soybean or faba bean tempehs led to decrease in antinutritional components (phytic acid, trypsin inhibitor activity and total vicine). Frying process led to significant decrease ( $P < 0.05$ ) in these antinutritional components of "Taameia" and all tempeh products. Processing of faba bean tempeh products minimized these antinutritional components compared to "Taameia". Processing of soybean tempeh products also minimized trypsin inhibitor activity and total vicine compared to "Taameia", but their phytic acid contents were not less than that



of "Taameia". This is due to the largest amount of phytic acid in soybean at zero time of fermentation.

10- Statistical analysis indicated that there is not significant difference ( $P>0.05$ ) between soybean tempeh mixed with green spices and "Taameia" from the stand point view of flavor and odor. Statistical analysis did not indicate any significant differences ( $P>0.05$ ) between soybean and faba bean tempehs without green spices for flavor, odor, color and appearance. Average scores of flavor and odor of soybean tempeh mixed with green spices were significant higher ( $P<0.05$ ) than those of soybean without green spices and faba bean tempeh products. Statistical analysis indicated that "Taameia" obtained the higher scores for color, texture and appearance. With respect to tempeh products, soybean tempeh mixed with green spices obtained the higher scores for color, texture and appearance compared to the other tempeh products. With respect to overall acceptability, there was no significant difference between soybean tempeh mixed with green spices and "Taameia".

11- Using of Rhizopus oligosporus to produce soybean or faba bean tempehs led to decrease their mineral elements. This decrease is parallel to high decrease in ash content during tempeh production. Addition of green spices led to increase all elements except Fe in soybean or faba bean

tempehs. Each product was characterized by having higher concentration of one or more mineral elements than the other products. For example soybean tempeh mixed with green spices having higher concentration of Ca, K, P, Na, Mn and Cu; "Taameia" paste was having higher concentration of Fe and Zn and faba bean tempeh mixed with green spices having higher concentration of Mg than the other products tested. Frying process led to decrease all mineral elements of "Taameia" and all tempeh products.

12- Palmitic acid ( $C_{16:0}$ ) constituted the major saturated fatty acids in "Taameia" paste, soybean and faba bean cotyledons at zero time of fermentation and tempeh produced from these cotyledons. Stearic acid ( $C_{18:0}$ ) constituted the second major saturated fatty acids of "Taameia" paste, soybean and faba bean cotyledons at zero time of fermentation and tempeh produced from these cotyledons. Linoleic acid ( $C_{18:2}$ ) constituted the major unsaturated fatty acids of soybean and faba bean cotyledons at zero time of fermentation and soybean and faba bean tempehs. It constituted the second major unsaturated fatty acids of "Taameia" paste. Oleic acid ( $C_{18:1}$ ) constituted the major fatty acid of "Taameia" paste while it constituted the second major unsaturated fatty acids of soybean and faba bean cotyledons at zero time of fermentation and soybean and faba bean tempehs. Linolenic acid ( $C_{18:3}$ )

constituted the least unsaturated fatty acids of all products. Addition green spices led to increase palmitic and oleic fatty acids, while it decreased stearic, lenoleic and lenolenic fatty acids of soybean or faba bean tempehs. Frying process led to increase palmitic, stearic and oleic fatty acids, while it decreased lenoleic and lenolenic fatty acids.

### CONCLUSION AND RECOMMENDATION

The obtained results indicated that excellent tempeh was prepared from soybean and faba bean seed after soaking for 24 hr, dehulled by hand, cooked at 100°C for 30 min., cooled to room temperature and inoculated with spores suspension of the mold Rhizopus oligosporus. The inoculated bean cotyledons were inocubated at 31°C for 36 hr to produce fresh tempeh.

The obtained tempeh is perffered to be mixed with green spices before frying process for 5 min. in boiled oil. The final fried products will be with high protein content and very low level of the antinutritional components (phytic acid, trypsin inhibitor activity and total vicine). Soybean tempeh containe 1.08 mg/g, 1.14 TIU/mg and 0.32 mg/g and faba bean tempeh containe 0.29 mg/g, 0.75 TIU/mg and 0.87 mg/g of these components, respectively. These components were removed in percentage of 89.36, 97.26 and

93.81%, from soybean cotyledons. They were removed from faba bean cotyledons in percentage of 84.82, 96.64 and 94.57%, respectively.

It is important to mention here that soybean is cheaper than faba bean. The price of faba bean is about three times of price of soybean. So soybean could be recommended to produce new popular products which is soybean tempeh mixed with green spices. It is believed that more study on the other antinutritional components such as lectins, tannins and stachyose will result in more credits to produce and consume this product.