International Food Research Journal 22(2): 510-516 (2015)
Journal homepage: *http://www.ifrj.upm.edu.my*

Application of taguchi method in optimization of process factors of ready to eat peanut *(Arachis hypogaea)* Chutney

*Chandrasekar, V., Kannan, K., Priyavarshini, R. and Gayathri, R.

Department of Food Technology, Kongu Engineering College, Perundurai, Erode, 638052, Tamil Nadu, India

Article history

Received: 25 June 2013
Received in revised form: 2 September 2014
Accepted: 5 September 2014

Keywords

Peanut chutney
Taguchi optimization
Signal to noise ratio
Quality parameters

Abstract

Taguchi orthogonal array method was used to optimize the process factors for developing ready to eat peanut chutney. Different treatments were obtained by L_4 (2^3) of Taguchi orthogonal array and prepared ready to eat peanut chutney was stored according to treatments. Signal to noise ratio is the statistic of Taguchi orthogonal array and it was calculated. Quality parameters such as free fatty acid, peroxide value and total phenolic content were estimated after 40th day. Free fatty acid, peroxide value and total phenolic content were varied between 0.44 to 0.23 % of oleic acid, 28.7 to 51.5 meq/ kg and 1.76 to 4.7 mg/g, respectively. Treatments were analyzed and process factors were optimized based on the quality parameters. Optimized the treatment was treatment 3 i.e. A_2 vinegar percentage (10%), B_1 packaging material (Glass bottle) and C_2 storage condition (Refrigeration temperature, 5±2°C). Optimized treatment was confirmed with experimental results.

Introduction

Peanut *(Arachis hypogaea)* are known by many names such as earthnut, ground nut, monkey nut, pygy nut and pig nut. Annual production of Indian peanuts is 5-8 million and 1.5 million tons. Peanuts are good sources of dietary protein composed essential amino acids, resveratrol, vitamin E and B-complex and minerals. Peanut also contains a reasonable amount of mono-unsaturated fatty acids and polyphenol content. Peanuts are having many uses like eaten as raw, used for oil extraction, and used in recipes for chutney. Chutney is an important dish in Indian cuisine. They are made from fruits or vegetables, or a mixture of the two, which are chopped, cooked, mixed with spices, vinegar and other ingredients and reduced to a smooth pulp. Chutneys and pickles are eating along with rice and breakfast items like chapatis, idly, dosa, and vada in India. Chutneys are either wet or dry and they are preserved in several ways such as using oil, vinegar or citrus juice fermentation in the presence of salt. Vinegar is the main ingredient in all chutneys and acid of the vinegar acts as a natural preservative and enhance the keeping quality (Srivastava *et al*., 2002). Several instant chutney powders and chutneys were reported by Satyanarayana *et al.* (2001) for pudina and gongura instant chutneys; Balaswamy *et al.* (2004) for curry leaf chutney powder; Rao *et al.* (2004) for tamarind leaf chutney powder; Jyothirmayi *et al.* (2006) for raw tamarind chutney powder; Narsing Rao *et al.* (2008) for raw mango chutney powder. Murray *et al.* (2001) used the hedonic scale method to optimize the ingredients based on colour, taste, flavor, consistency and overall acceptability. A 9 point hedonic scale sensory analysis was made for instant raw mango chutney powder (Narsing Rao *et al*., 2008) and for ready to eat amla chutney (Mishra *et al*., 2011). Keeping quality of peanut chutney relies upon the free fatty acid (FFA), peroxide value (PV) and total phenolic content (TPC). FFA content was increased from 0.30% to 1.58% after 128 days of storage in milled flaxseed (Malcolmson *et al.*, 2000). Free fatty acid content was increased during storage of flaxseed chutney powder (Rao *et al*., 2013). Frankel (1998) observed that the degradation rate of unsaturated fatty acids and the formation rate of the hydrogen peroxides were low at initial days and increased rapidly after the induction period. The lipid quality of anchovies was expressed as peroxide value and the range was between 2.2 to 4.3 meq.of O_2/kg of fat (Dipty *et al.*, 2010). Galla Narsing Rao *et al*. (2011) observed that the total polyphenol was increased from 462.4 to 1164.0 for white aril powder and 829.8 to 953.2 for pink aril powder. The total polyphenol content was increased in instant tomato pickle mix packed in polyethylene (Narsing Rao *et al*., 2011) during storage and in instant pulihora mix (Prabhakara Rao *et al*., 2012) after six months.

Taguchi orthogonal array method was used to study the effect of interaction among the process parameters (Barua *et al*., 1997) and used to optimize the microwave power level and time for microwave

*Corresponding author.
Email: *chandrufpe@gmail.com*

frying of potato slices (Mecit Halil Oztop *et al.*, 2007) and used to achieve high quality of fermentation by reducing the number of experiments (Chao-Chin Chung *et al*., 2008). Ravella Sreenivas Rao *et al.* (2008) reported the applications of Taguchi method in the field of fermentation, food processing, molecular biology, wastewater treatment and bioremediation. Ho-Hsien Chen *et al.* (2011) stated that the Taguchi method can be used to optimize the factors in food science and engineering. Standard deviation measures the variation from the expected value. A lower standard deviation indicates that the response values are close to the expected value and high standard deviation indicates that the response values are spread out from the expected value due to noise factors. Noise factors are difficult to control. Both the response value and noise factor are to be controlled by a single term of merit called Signal to Noise ratio. Signal to Noise (SN) ratio is the inverse of the coefficient of variation and unit less value, which is an unbiased measurement to measure the dispersion by taking log transformation (Besterfield *et al*., 2012). Signal to noise (SN) ratio measures the effect of noise factors on performance characteristics and quantifies the variability.

Though, there is no scientific study available for ready to eat peanut chutney and process optimization by Taguchi method. Hence, the aim of the study was to optimize the process parameters of the ready to eat peanut chutney by Taguchi method.

Materials and Methods

Materials

Peanut and all the required ingredients were purchased from the local market, Perundurai, Erode district and work was carried out at Food Process Engineering laboratory, Kongu Engineering College, Erode.

Design of experiments

The peanuts were roasted with sand at 100-110^{o}C and other ingredients such as curry leaves, cumin, asafetida and garlic were fried with oil. Roasted peanuts, fried ingredients, chilli powder, tamarind and salt were ground together along with water and thus prepared the ready to eat chutney. Experiments were designed using Taguchi orthogonal array method of L_4 (2^3). Factors and levels of the experimental studies and four treatments with balanced effect are shown in the table 1. The prepared ready to eat chutney was packed and stored at different treatment conditions obtained by Taguchi orthogonal array L_4 (2^3) method.

Table 1. Factors and levels

No	Name of the factors and symbols	Level	
		1	2
1	Vinegar (A)	5%	10%
2	Packaging material (B)	Glass bottle	Aluminum foil
3	Storage temperature (C)	Room temperature (35±2^{o}C)	Refrigeration temperature (5±2^{o}C)

Quality analysis

All the quality analysis was done by Sadasivam and Manickam (1997). Five grams of the sample was taken in a 250 ml conical flask and dissolved with neutral solvent (Mixture of 25 ml of ether, 25 ml of 95% alcohol and 1ml of 1% phenolphthalein solution and neutralize with N/10 alkali) until get a colorless solution. Few drops of phenolphthalein was added to the colorless solution and titrated against the 0.1N potassium hydroxide. The appearance of pink color and persisting for 15 seconds was the end point. Concordant values were taken and calculated the free fatty acid content using the equation 1 and expressed as percentage of oleic acid.

$$\text{FFA, \% of oleic acid} = \frac{\textit{Titre value} \times 0.028 \times 56.1}{\textit{Weight of the sample, g}} \times 100 \quad (1)$$

One gram of sample was taken into a clean dry boiling tube. 1g of powdered potassium iodide and 20 ml of solvent mixture (Two volumes of glacial acetic acid added with one volume of chloroform) were added to the boiling tube. The solution was boiled for 30 seconds in a water bath. Boiled solution was transferred to a conical flask containing 20 ml of 5% potassium iodide solution and washed the boiling tube with 25 ml of water for twice. The washed water was also collected into the conical flask. The solution in the conical flask was titrated against the N/500 sodium thiosulphate until yellow the color disappeared. After that 0.5 ml of starch was added to the conical flask and shake vigorously till the blue color appeared. Again the solution was titrated against with N/500 sodium thiosulphate solution carefully till the blue color disappeared and noted as T_1. A blank was also done and the titrated value was noted as T_2. The peroxide value of the sample was calculated by the formula (equation 2) and expressed as meq/kg of sample.

$$\text{Peroxide value (meq/ kg of sample)} = \frac{(T_1 - T_2) \times 0.002 \times 1000}{\textit{kg of sample}} \quad (2)$$

One gram of sample was ground with 10 fold volume of 80% of ethanol in a pestle and mortar to homogenate. Homogenate was centrifuged at 10000

Table 2. Taguchi orthogonal array L_4 (2^3) design and response

Factors and Levels			Treatment	FFA,	PV,	TPC,	Overall
A	B	C	No	%	meq/kg	mg/100g	acceptability
1	1	1	T1	0.44	51.6	4.7	5.8
1	2	2	T2	0.38	45.8	3.9	6.2
2	1	2	T3	0.23	28.7	1.76	7.6
2	2	1	T4	0.33	37.6	2.8	6.1

rpm for 20 minutes and collected the supernatant. The residue was re-extracted with 5 fold volume of 80% ethanol and pooled the supernatant after centrifuge. The supernatant was dried to remove ethanol and dissolved in 5 ml of distilled water. Aliquots were prepared from 0.2 to 2 ml into test tubes and made up the volume into 3 ml with distilled water. 0.5 ml of Folin-ciocalteau reagent was added to the test tubes. After 3 minutes, 2 ml of Na_2Co_3 solution was added to each tube and mixed thoroughly. The tubes were kept in a water bath exactly for one minute. Boiled tubes were cooled and measured the absorbance at 650 nm against the reagent blank. The standard curve was made using different concentrations of catechol. From the standard curve, the concentration of phenol in the samples was determined and expressed as mg/100 g of sample.

Process optimization

The average mean of the response for the each level of the factors was calculated. The average mean of the response for level 1 of a factor was calculated by taking average of the mean value of the response of treatments which included the level 1 of a particular factor. Similarly, average SN Ratio was also calculated for each level of all factors. The lesser amount of free fatty acid, peroxide value and the total phenol content and larger sensory score indicates the good quality of the product. Hence, Smaller the Better (equation 3) formula was used for calculating the signal to noise ratio of free fatty acid, peroxide value, total phenol content and Larger the Better formula (equation 4) was used for calculating the signal to noise ratio of overall acceptability.

$$S/N_{STB} = -10\log_{10}\left(\frac{\sum y^2}{n}\right) \quad (3)$$

$$S/N_{LTB} = -10\log_{10}\left(\frac{\sum\left(1/y^2\right)}{n}\right) \quad (4)$$

Where, STB is smaller the better, LTB is larger the better, y is the response and n is the number of treatments. The statistics and average of the statistic are used to check the effect of factors and their levels on quality parameters by plotting the graph between the average value of the statistic and the factors and their levels.

Result and Discussion

Analysis of design

Taguchi orthogonal array method is a scientific method of arranging factors and levels in column and row matrix to draw out the experiments and provides a balanced effect of factors on each experiment. Taguchi designs are saturated orthogonal arrays of all main effects. The L and the subscript represent the Latin square and the number of experimental runs, respectively. Ready to eat chutney was prepared and packed based on the treatments the L_4 (2^3) of Taguchi orthogonal array method. Taguchi orthogonal array method compares the experiments and optimizes the experiments with less variability. All the quality analyses were carried out as triplicate samples after 40 days of storage period. Response and SN ratios of the treatments were analyzed using the MINITAB 16 statistical software package to obtain the main effects of the factors and their levels. Optimized factors and levels were selected based on the desired quality conditions for the more keeping quality of the ready to eat peanut chutney.

Optimization of process factors

Responses of the treatments were analysed by graphical method. The average mean and average SN ratio of quality parameters are given in the table 2 and shown in the Figures from 1 to 8. Higher value of quality parameters lesser keeping quality and lower value of quality parameters indicates the more keeping quality. All the three factors strongly affected the average mean of free fatty acid (Figure 1) and also had a strong effect on the average SN ratio of the free fatty acid (Figure 5). SN ratio is the logarithmic function of desired quality parameters and used as a goal function for optimization. Regardless of the category of SN ratio, higher SN ratio was considered for the optimized value (Prabir and Reeta, 2008). A_2, C_2 and B_1 have shown lesser average mean content and higher SN ratio of free fatty acid. It demonstrated that the level 2 of factor A and C and the level 1 of factor B were found to be a better treatment.

Low peroxide value indicates the lesser development of rancidity in the product and thus increases the consumer acceptance of the product. The effect of factors and levels on the average mean of peroxide value is shown in the Figure 2 and it is

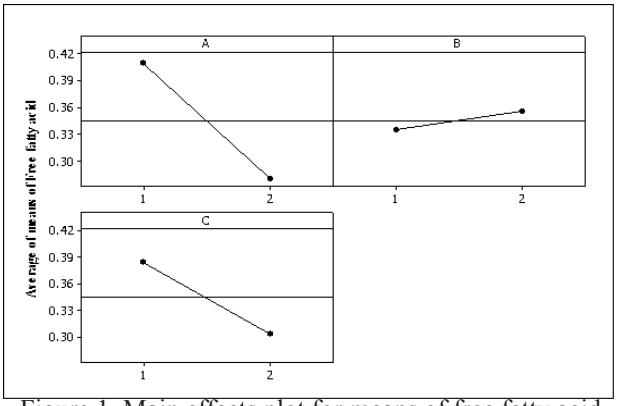

Figure 1. Main effects plot for means of free fatty acid

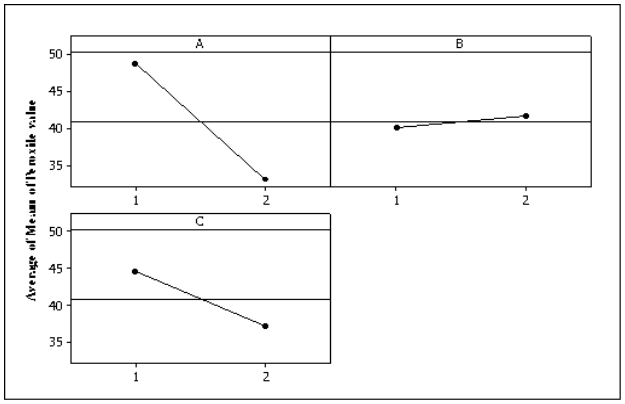

Figure 2. Main effects plot for means of peroxide value

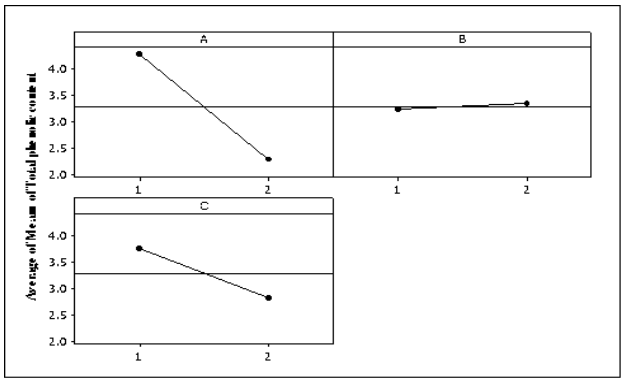

Figure 3. Main effects plot for means of total phenolic content

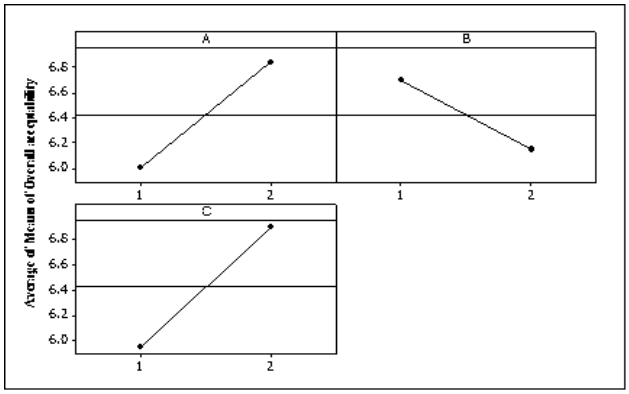

Figure 4. Main effects plot for means of overall acceptability

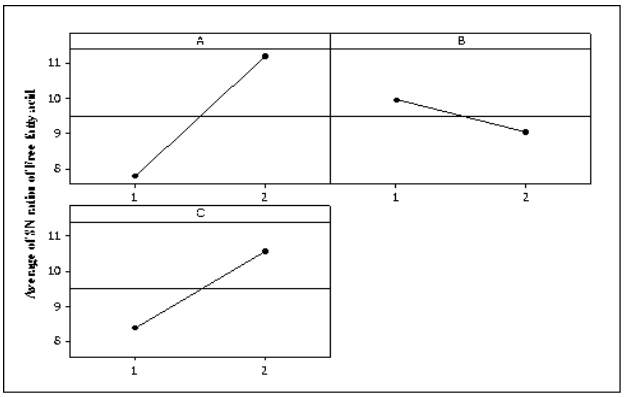

Figure 5. Main effects plot for SN ratios of free fatty acid

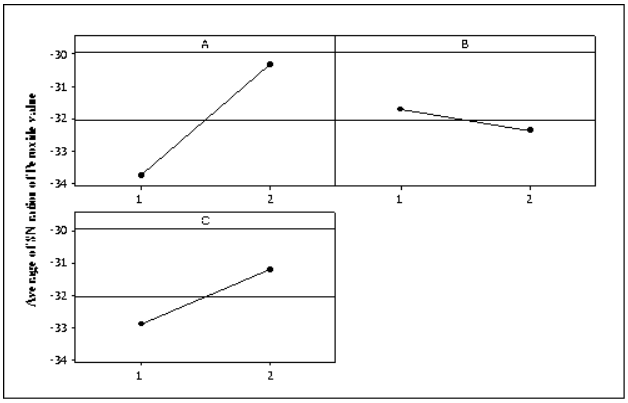

Figure 6. Main effects plot for SN ratios of peroxide value

observed that the A_2, and C_2 strongly influenced the peroxide value. B1 had not affected the peroxide value reasonably. Similarly, the effect of factors and levels on SN ratio of peroxide value was affected by all the three factors shown in the Figure 6. Though the less influence of factor B on average mean of peroxide value, factors B affected the SN ratio of peroxide value. It is inferred that the factor B had little effect on peroxide value.

Average mean value and SN ratio of total phenolic content was estimated and shown in the Figures 3 and 7. From the Figure 3, it is observed that the factor A and C are reasonably affected the total phenolic content than the factor B. This could be the due to both vinegar and storage temperature prevents availability of total phenolic content to the enzyme and the less permeability of the packaging material prevents the availability air for reaction with total phenol. A reasonable influence of A, B and C on SN ratio of total phenolic was found in the Figure 7. Nonetheless, factor B had not affected the average mean, it affected the SN ratio. These results are in accordance with the results of Dobrzanski *et al.* (2007) and Ho-Hsien Chen *et al*. (2011).

Overall acceptability is an important attribute for development of food product. Overall acceptability is a sensory evaluation, which indicates the consumer acceptability of the product. The response analysis for the overall acceptability was made. Higher, overall acceptability indicates the higher quality.

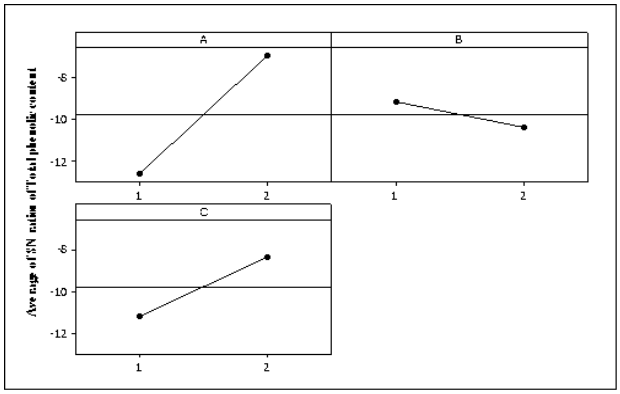

Figure 7. Main effects plot for SN ratios of total phenolic content

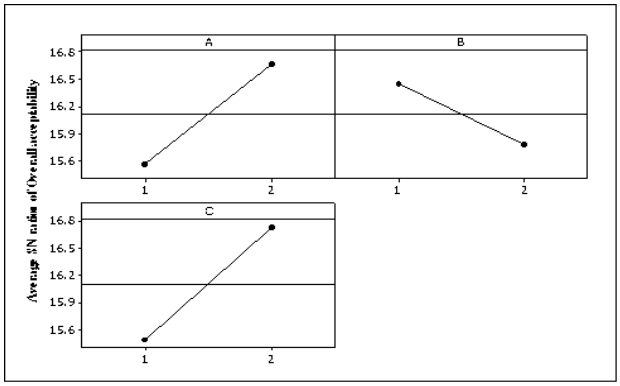

Figure 8. Main effects plot for SN ratios of overall acceptability

From the Figure 4 and 8, it is observed that all the factors had influenced the overall acceptability of the product. Based on the quality analysis and overall acceptability, treatment 3 i.e. A_2, B_1 and C_2 was found to have good keeping quality of chutney and no similar studies has been reported so far.

Experimental results

Response of the each treatment was analysed confirming the optimized results from the Taguchi method of treatments. Higher the free fatty acid content of 0.44 % was observed in treatment 1 (T1), it might be due to the conversion of fat into fatty acids which leads to the rancid flavor to end product. An increase in free fatty acids during storage period is might be due to hydrolysis of fat (Malcolmson *et al*., 2000; Dipty *et al*., 2010). A lower free fatty acid of 0.23%, 0.33 and 0.38 was found in treatment 3 (T3), treatment 4 (T4) and 2 (T2), respectively. It shows that lesser vinegar percentage decreased the keeping quality. From the results, it is observed that the storage temperature also affected the keeping quality. Higher free fatty acid content was found in product stored at room temperature. Development of peroxides affects the sensory quality of foods and it is an indicator of oxidative rancidity of food. Amount of peroxides present in the sample is called as peroxide value. Increased peroxide value decreases the keeping quality of the product and which causes the off flavor to the product. Peroxide formation during storage was may be due to oxidation of unsaturated fatty acids (Frankel, 1998). Higher peroxide value of 51.6 meq/kg was recorded in treatment 1 (T1) and a lower peroxide value of 28.7 meq/kg was recorded in treatment 3 (T3). Similarly, increased total phenolic content of 4.7 mg/g was observed in the treatment 1 (T1) and total phenolic content 1.76 mg/g of treatment 3 (T3) was observed less changes during storage period. The stability of the total phenol content indicates the less amount quality degradation. Increased amount of total phenolic content was due to oxidation and releasing of bounded phenol by enzymatic reaction during storage (Jyothirmayi *et al*., 2006; Guizhi Zhang *et al*., 2008). Maisuthisakul *et al*. (2011) observed that the total phenolic content was increased as increased temperature. From the results, it is observed that the storage temperature was primarily influenced the keeping quality of the product (Mishra *et al*., 2011). Next to storage temperature, the vinegar percentage influenced the keeping quality. Acid content of the vinegar arrests the microbial load and thus prevents the development of enzymatic browning and rancidity. Though the no strong influence of packaging material was observed on quality parameters, glass bottle storage was found to be better compared to refrigeration storage. This could be due to good barrier property of the both packaging material (Galla Narsing Rao *et al*., 2011). Hence, the treatment 3 (T3) was found better for storage of peanut chutney upto 40 days without any spoilage. This was also confirmed by the high overall acceptability as 7.6 of the product after 40th day of storage. Values of the overall acceptability were also accordance with the quality analysis.

Conclusion

To conclude, Taguchi orthogonal array method can be used to optimize the process factors of ready to eat the peanut chutney development based on desired quality parameters value such as free fatty acid, peroxide value and total phenol content. The statistics for the quality parameters were calculated and the interaction graph was plotted using statistics. From the graphs, all the factors have been found reasonably influenced the quality parameters after 40th day. Treatment condition i.e A_2 (Vinegar percentage, 10%), B_1 (packaging material- glass bottle) and C_2 (storage condition- Refrigeration temperature) is

optimized for storing of ready to eat peanut chutney for 40 days.

Acknowledgement

We sincerely express our gratitude to Kongu Engineering College for facilities provided.

References

Balaswamy, K., Jyothirmayi, T. and Rao, D. G. 2004. Studies on preparation of curry leaf *(Murraya koenigii)* chutney powder. Journal of Food Service Research Institute 14: 175-187.

Barua, P. B., Kumar, P. and Gaindhar, J. L. 1997. Surface roughness optimization of V-process casting through casting method. AFS transition 45: 733-768.

Besterfield, D.H., Carol Besterfield-Michna, Besterfield, G.H., Mary Besterfield-Sacre, Hemant Urdhwareshe and Rashmi Urdhwareshe. 2012. Total Quality Management, revised third ed. Pearson Education, Prentice Hall, India.

Chao-Chin Chung, Ho-Hsien Chen and Pao-Chuan Hsieh. 2008. Optimization of the *Monascus purpureus* Fermentation Process Based on Multiple Performance Characteristics. Journal of Grey System 11 (2): 85-96.

Dipty, A. S., Khedkar, G. D. and Sudhakara, N. S. 2010. Preparation of pickled product from anchovies (*Stolephorus* sp.) and studies on quality changes during storage. Journal of Food Processing and Preservation 34: 176–190.

Dobrzanski, L. A., Domaga, J. and Silva, J. F. 2007. Application of Taguchi method in the optimisation of filament winding of thermoplastic composites. Archives of Materials Science and Engineering 28 (3): 133-140.

Frankel, N., 1998. Lipid Oxidation. The Oily Press, Dundee (UK).

Galla Narsing Rao., Allani Nagender., Satyanarayana, A. and Dubasi Govardhana Rao. 2011. Preparation, chemical composition and storage studies of quamachil *(Pithecellobium dulce)* aril powder. Journal of Food Science and Technology 48 (1): 90–95.

Guizhi Zhang, Baoping Ji, Bo Li, Fang Tian, Gang Chen, Fengdi Ji, Hongjuan Zhang, Zhiwei Yang, and Lei Zhao. 2008. Effects of processing and storage condition on phenolic concentrations and antioxidant activities of apple and apple juices. Journal of Food Science and Technology 45 (4): 339-343.

Ho-Hsien Chen, Chao-Chin Chung, Han-Yan Wang and Tzou-Chi Huang. 2011. Application of Taguchi Method to Optimize Extracted Ginger Oil in Different Drying Conditions. International Conference on Food Engineering and Biotechnology, Vol. 9, IACSIT Press, Singapore.

Jyothirmayi, T., Rao, G. N. and Rao, D. G. 2006. Studies on instant raw tamarind chutney powder. Journal of Food Service Research Institute 17: 119-123.

Maisuthisakul, P. and Gordon, M. H. 2011. Characterization and storage stability of the extract of Thai mango (*Mangifera indica* Linn. Cv. Chok-Anan) seed kernels. Journal of Food Science and Technology: 1-10.

Malcolmson, L. J., Przybylsky, R. and Daun, J. K. 2000. Storage stability of milled flaxseed. Journal of American Oil Chemical Society 77: 235-238.

Mecit Halil Oztop, Serpil Sahin and Gulum Sumnu. 2007. Optimization of microwave frying of potato slices by using Taguchi technique. Journal of Food Engineering 79 (1): 83-91.

Mishra, P., Verma, M., Mishra, V., Mishra, S. and Rai, G.K. 2011. Studies on development of ready to eat Amla *(Emblica Officinalis)* chutney and its preservation by using class one preservative. American Journal of Food Technology 6 (3): 244-252.

Murray, J. M., Delahunty, C. M. and Baxter, I. A. 2001. Descriptive sensory analysis-past, present, future. Food Research International 34: 461-471.

Narsing Rao, G., Prabhakara Rao, G., Jyothirmayi, T. and Rao, D. G. 2008. Chemical composition, standardization and storage studies on raw mango chutney powder. Journal of Food Science Technology 45: 436-438.

Narsing Rao, G., Prabhakara Rao, G., Balaswamy, K. and Rao, D. G. 2011. Preparation of instant tomato pickle mix and evaluation of its storage stability. International Food Research Journal 18: 589-593.

Prabir, K. C. and Reeta, D. 2008. Process parameter optimization for fly ash brick by Taguchi Method. Materials Research 11 (2): 159-164.

Prabhakara Rao, G., Narsing Rao, G., Nagender, A. Jyothirmayi, T. and Satyanarayana, A. 2012. Standardization, chemical characterization and storage studies of an instant pulihora mix based on raw mango. Indian Journal of Traditional Knowledge 11 (1): 90-95.

Ravella Sreenivas Rao, Ganesh Kumar, Shetty Prakasham, C. R., and Phil J. Hobbs. 2008. The Taguchi methodology as a statistical tool for biotechnological applications: A critical appraisal. Biotechnology Journal 3: 510-523.

Rao, P. G., Rao, N. G., Satyanarayana, A and Rao, D. G. 2004. Studies on chutney powders based on tamarind *(Tamarindus indica)* Leaves. Journal of Food Service Research Institute 15: 13-24.

Rao, P. P., Rao. G. N., Mala, K. S. Balaswamy, K. and Satyanarayana, A. 2013. Preparation and storage stability of flaxseed chutney powder, a functional food adjunct. Journal of Food Science and Technology 50 (1): 129–134.

Sadasivam, S. and Manickam, A. 1997. Biochemical Methods, (2nd Edn) New Age International Publishers, New Delhi.

Satyanarayana, A., Giridhar, N., Balaswamy, K. Shivaswamy, R. and Rao, D. G. 2001. Studies on development of instant chutneys from pudina (Mint, *Mentha spicata*) and gongura (*Hibiscus* sp.). Journal of Food Science and Technology 38 (5): 512-514.

Srivastava, R. P. and Kumar, S. 2002. Fruits and vegetable Preservation, Third edition. International Book

Distributing Co. Lucknow, India.