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Development of shelf stable tomato *rasam* paste using hurdle technology

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Abstract

The objectives of this work were to develop ready-to-use tomato rasam paste using hurdle technology involving water activity (a_w), temperature, pH and preservative as hurdles and evaluation of shelf stability of the developed product. Physico-chemical characteristics such as pH, titratable acidity (TA), colour changes, and microbiological profiles were evaluated during storage of 4 months at ambient temperature (AT, 28 ± 4ºC) and 37ºC. Hunter color analysis showed significant (P<0.05) decrease in the lightness (L^*) and redness (a^*) while yellowness (b^*) of paste increased during storage at both the storage temperatures. The L^* value decreased from 27.23 to 20.78 and 18.23 in samples stored at AT and 37ºC, respectively while a^* values decreased from 34.29 to 30.02 and 31.21 in samples stored at AT and 37ºC, respectively. The paste was found to be acceptable on sensory scale after 4 months of storage at ambient temperature. The quality of paste in terms of sensory colour attribute was found to be deteriorated in sample stored at higher (37ºC) temperature.

Introduction

Rasam is a very popular spice stock preparation of India. It is consumed on daily basis in south Indian homes. Rasam is prepared from a variety of spices and condiments which are considered to be good for health and improving the digestion (Krisnapura, 2005). The strong blended flavour of spices used in rasam preparation makes it unique in taste and flavour. Rasam is relished along with rice and breakfast foods such as *chapati*, *dosa*, *uttapam*, *idli* etc. The main spices and condiments used in rasam preparation are coriander leaves, garlic, curry leaves, jaggary, tamarind puree, cumin, black pepper, mustard seeds, turmeric, red chilli, asafoetida and salt. As rasam is only a stock of spice extract, appropriate thickeners are added in the preparation for the desired consistency. Tomato pulp can be added to the rasam stock to increase the solid content, consistency as well as sensory acceptability.

Tomato is an economically important vegetable crop widely grown in India. The nutritional value of tomato is due to its rich organic acids and phenolics which have also been correlated with high biological activity in the human body (Stahl and Sies, 1996; Giovanelli *et al*., 2001; Giovanelli and Paradiso, 2002). Tomatoes are a rich source of lycopene (60-90 mg/kg) (Charanjeet *et al*., 2004). However lack of sufficient post-harvest strategies, poor transportation and storage facilities contribute to very high tomato wastage. Tomatoes are mostly used in the preparation of puree, ketchup, soup and paste apart from fresh consumption (Shi and Le Maguer, 2000). A new range of processed traditional products from tomatoes can be introduced in the market to give diversification and reduce post harvest losses. In this regard, shelf-stable ready-to-use tomato rasam paste may be an ideal product for saving time and energy of the consumers.

Hurdle technology (HT) is a concept for the production of safe, stable, nutritious, tasty and economical food using deliberate combinations of existing and novel preservation techniques by applying various hurdles so that any micro-organism should not be able to overcome the hurdles (Leistner, 2000). It requires a certain amount of effort from a micro-organism to overcome each hurdle. The 'higher' the hurdle, the greater the effort (i.e. the larger the number of organisms needed to over come it) (Saxena *et al*., 2009). The hurdles can be temperature, water activity (a_w), pH, redox potential, preservatives, and so on. Some hurdles, like pasteurization, can be high for a large number of micro-organism whereas others, like salt content, have a less strong effect or the effect is limited to different types of micro-organisms (Leistner and Gorris, 1995). Appropriate selection and magnitude of hurdles play an important role in achieving the microbial stability in hurdle technology without impeding the vital nutrients and sensory properties of the product (Vibhakara, 2007). Hence, the objectives of the present study were to develop

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Table 1. Standardized recipe for the preparation of tomato rasam paste

Ingredients	Level (%)
Tomato Pulp	21.85
Cumin	5.46
Black Pepper	5.46
Turmeric	1.09
Red Chilly Powder	5.46
Mustard Seeds	3.28
Jaggary	10.92
Fenugreek	1.09
Asafoetida	0.54
Oil	10.92
Salt	4.37
Tamarind	5.46
Coriander leaves	5.46
Curry leaves	5.46
Garlic	10.92
Citric acid	0.1

ready-to-use tomato *rasam* paste stabilized by hurdle technology and to evaluate the shelf stability of the developed product in terms of physico-chemical, microbiological and sensory characteristics during four months of storage at different temperature conditions.

Materials and Methods

Tomatoes

Fully ripe red tomatoes devoid of any blemishes, any visible sign of microbial infection and physical injury were purchased from the local market of Mysore, Karnataka and stored at low temperature (6°C) until processing. Tomatoes were given a phyto-sanitation wash in 30 ppm chlorinated water for 5 minutes. Tomatoes were cut into halves and then heated at 80°C for 2 min and pulped through a pulper (Siemen, India) equipped with stainless steel screen to remove skin and seeds. Total soluble solid content (TSS) and pH of the pulp was found to be 6 °brix and 4.2, respectively.

Preparation of tomato rasam *paste*

The recipe of tomato rasam paste was standardized based on preliminary sensory trials conducted in the laboratory with the help of semi-trained scientific staff of the laboratory. The standardized formulation of tomato rasam paste is given in Table 1. Dry whole spices such as cumin, black pepper and fenugreek seeds were roasted separately for 2 minutes at 150°C before grinding to get fine powder. Fresh green coriander leaves, curry leaves and garlic cloves were washed thoroughly in chlorinated water (30 ppm) for 5 minutes and then the green leaves were soaked in 0.1% magnesium oxide and sodium bicarbonate solution for 10 minutes to prevent discolouration during processing.

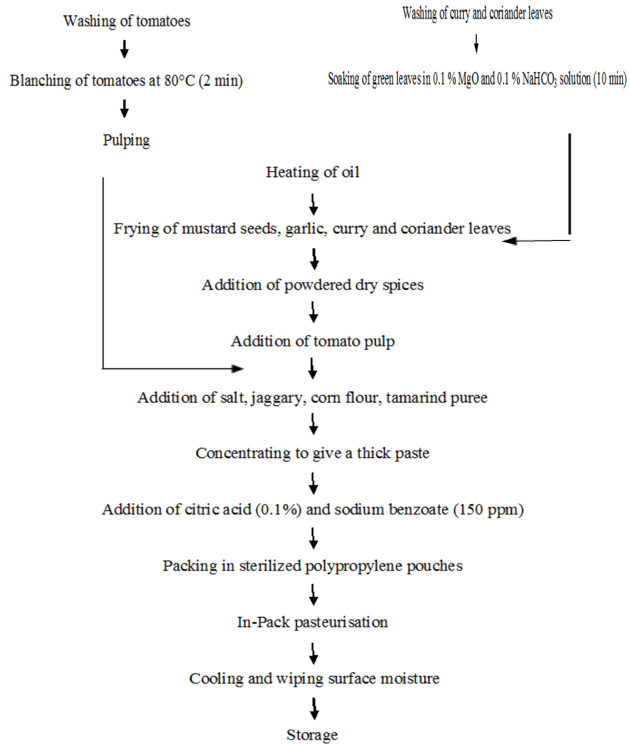

Figure 1. Flow diagram of *rasam* paste preparation

Sunflower oil was heated in a wok and mustard seeds were added. After complete cracking of mustard seeds, previously roasted and powdered dry spices were added and sautéd. Chopped coriander leaves, curry leaves and garlic paste were added into mixture and fried. Tomato pulp was added after complete sautéing of all the spices. Salt, jaggary, corn flour, tamarind were also added at this stage. The mixture was concentrated in a concentrator (M/s Sunray Industries, Mysore) by constant stirring to get a thick paste. The mixture was concentrated up to aw of 0.90. Citric acid (0.1%) was added at the end of the cooking. Sodium Benzoate was added as preservative (150 ppm) to the concentrated paste. 100 g of tomato rasam paste was filled into clean and sterilized polypropylene pouches (25 µm). In-pack pasteurization of the sealed pouches was carried out by dipping them in boiling water for 15 minutes. After in-pack pasteurization the pouches were cooled immediately. Surface moisture of the pouches was removed by wiping it with clean muslin cloth. Pouches were kept at ambient temperature (28±4ºC) and 37ºC for the storage studies (Figure 1).

Physico-chemical analyses

Tomato rasam paste samples were randomly

Table 2. Changes in physico-chemical properties of tomato *rasam* paste during storage (*n*=4)

Storage period (days)	Storage temperature (°C)	Moisture (%)	Acidity (% citric acid)	pH	NEB (absorbance at 420 nm)	a_w
0		55.62a	2.12a	4.02a	0.218a	0.906a
30	28±4	54.49a	1.98a	4.11a	0.256a	0.906a
	37	53.30a	1.96a	4.13a	0.289a	0.905a
60	28±4	52.91a	1.85b	4.13a	0.307a	0.906a
	37	51.82b	1.83b	4.18b	0.349b	0.905a
90	28±4	50.05b	1.74b	4.16b	0.365b	0.904a
	37	50.47b	1.71b	4.20b	0.408b	0.900a
120	28±4	49.83b	1.67c	4.21b	0.412b	0.903a
	37	47.62c	1.62c	4.29c	0.575c	0.896b

Mean values in same column with different letters differ significantly ($P<0.05$)

selected immediately after processing (zero time) and at regular intervals of one month to evaluate physico-chemical changes. The aw of the samples was determined using dew point equipment (Aqua Laboratory, Decagon CX-2, Decagon Devices Inc., Pullman, Washington, USA) at 25°C while moisture and acidity of the samples were determined by standard procedures as described in AOAC (1997). The pH was estimated with a digital pH meter (Cyberscan, Eutech instruments, Singapore). During storage, the quality was also studied by evaluating the changes in peroxide value (PV), free fatty acids (FFA) as per AOAC (1997) while thio-barbituric acid (TBA) value was determined using the method reported by Tarladgis *et al*. (1960). All the estimations were made in four replications and reported the mean values.

Browning index

Non-enzymatic browning in terms of browning index (BI) was estimated by extracting 5 g tomato rasam paste sample in 100 mL ethanol (67%) for 1 h. This extract was filtered through Whatman No. 1 filter paper and browning index in terms of absorbance at 420 nm of the filtrate was measured with 67% ethanol as a blank.

Colour analyses

The Hunter color values of the tomato rasam paste samples were recorded using a colorimeter (Miniscan XE plus, Model No. 45/0-S, Hunter Associates Laboratory, Inc., Reston, VA, USA) which was calibrated using standard black and white ceramic tiles. The measurements were taken using D-65 illuminate and 10° observer. The colour values were expressed as L^* (whiteness or brightness/ darkness), a^* (redness/ greenness) and b^* (yellowness / blueness). The measurements were made in six replications and reported the mean values.

Sensory analyses

Tomato rasam paste sample after reconstitution with hot water was served to a semi-trained panel consisting of twenty members for sensory evaluation in terms of appearance, taste, flavour, texture and overall acceptability using a nine point Hedonic scale (Larmond, 1977) at zero day and at regular intervals during storage of four months. Panellists were scientific staffs of the laboratory who were trained in attributing rating for the characteristics examined. The scores were assigned from extremely liked (9) to disliked extremely (1). Samples were reconstituted and served in cups labelled with a random number in a room illuminated with white light at 25ºC. The panellists were asked to drink some water to cleanse the palate between tastes.

Microbiological analyses

The microbiological analyses in terms of standard plate count, yeasts and molds count were carried out using standard methodology (APHA, 2001) at zero time, and then at an interval of one month. Plate count agar (PCA) for determination of standard plate count and acidified potato dextrose agar (PDA) for determination of yeasts and molds count were used. Coliforms were determined using violet red bile agar. Numbers of micro-organisms were expressed as CFU g^{-1} of sample and evaluated in duplicates.

Statistical analysis

Statistical analysis was performed by analysis of variance (ANOVA) to calculate critical difference of the data to statistically predict the significance. Significance was established at $P < 0.05$ levels.

Table 3. Changes in rancidity parameters of tomato *rasam* paste during storage (*n*=4)

Storage period (days)	Storage temperature (°C)	PV (Meq of O_2/ Kg)	FFA (%)	TBA (Mal/kg)
0		12.68a	0.23a	0.051a
30	28±4	13.82a	0.98a	0.068a
	37	16.54b	1.22ab	0.119b
60	28±4	15.42a	1.56b	0.077a
	37	17.98b	1.89b	0.162b
90	28±4	18.23b	2.24b	0.132b
	37	21.52c	3.02c	0.204c
120	28±4	21.03c	3.45c	0.212c
	37	25.59d	4.46d	0.298d

Mean values in same column with different letters differ significantly ($P<0.05$)

Results and Discussion

Standardisation of recipe for tomato rasam *paste*

Hurdle Technology (HT) has been proved to be an important tool in preparation of shelf-stable, high moisture food products. In the present study, the hurdles involved in the development of rasam paste were pH, aw, temperature and preservative. The recipe of the rasam paste was standardised based on several preliminary sensory trials conducted in the laboratory. The standardised recipe and quantity of ingredients are presented in Table 1. The pH of rasam paste was lowered to 4.02 by adding tamarind and citric acid to ensure the microbial safety of the product. The water activity of the rasam paste wet mix was reduced from 0.906 to 0.896. Common salt, citric acid, tamarind and spices used in the recipe provided preservative effect. Sodium benzoate was also added as an anti-microbial agent with other hurdles to ensure the shelf-life of the paste. High moisture processed products can be stabilized up to few months by using various hurdles. Vibhakara *et al.* (2010) also reported development and stabilisation of high moisture green chutney by using combined preservation effect of various hurdles.

Physico-chemical changes during storage

The changes in physico-chemical characteristics of rasam paste stored at 37°C and ambient temperature (AT) during storage such as acidity, pH, moisture content and browning index are presented in Table 2.

Acidity and pH

The regulation of foods which are preserved by acidity requires a pH of 4.6 or less at which production of deadly toxins by the organism that causes botulism is inhibited (Mirian and Rosalia, 2005). Hence, as mentioned elsewhere, the pH of tomato *rasam* paste was reduced to 4.02. During storage the pH of paste was found to increase. The increase in pH was slow and gradual in paste stored at AT. However, it increased significantly ($P<0.05$) at higher storage temperature. At the end of 4 months of storage pH was increased to 4.21 in samples stored at room temperature and to 4.29 in samples stored at 37ºC. The acidity of the *rasam* paste was reduced from an initial value of 2.12 to 1.67% and 1.62% at the end of four months in *rasam* paste stored at AT and 37ºC, respectively.

Water activity and moisture

Reduction in aw was one of the most important hurdles performed during processing by concentrating tomato *rasam* paste. Addition of a variety of spices was also responsible for the reduced water activity of the final paste. The initial a_w of the paste was 0.896 which did not change significantly ($P>0.05$) over the storage period at different temperature conditions. The water activity was found to be 0.884 and 0.881 at the end of four months in the rasam paste stored at AT and 37°C, respectively.

The initial moisture content of the concentrated *rasam* paste was found to be 55.62%. The moisture content was decreased to 49.83% in AT stored samples and to 47.62% in samples stored at 37ºC at the end of four months. The decrease in moisture may be attributed to the desiccation of paste like materials during storage (Das and Radhakrishna, 2001).

Browning index

Browning index indicates the extent of non-enzymatic browning in a food product. It is an

Table 4. Change in colour attributes of tomato *rasam* paste during storage *(n*=6)

Storage period (days)	Storage temperature (°C)	L *	a *	b *
0		27.23a	34.29a	14.52a
30	28±4	24.88a	29.72a	14.55a
	37	20.13b	29.13a	14.80a
60	28±4	22.53a	27.74b	15.85a
	37	19.93b	26.54b	16.01ab
90	28±4	21.97a	26.56b	16.27b
	37	19.46b	25.04b	18.82b
120	28±4	20.78b	23.02c	19.51b
	37	18.23c	21.21c	21.01c

Mean values in same column with different letters differ significantly (*P*<0.05)

important parameter to judge the quality of the product during storage. Non-enzymatic browning is a common phenomenon in tomato based preparations (Madan *et al*., 2008). At the end of four months of storage, the reddish colour of tomato *rasam* paste turned into dark brown. As the tomatoes were given heat treatment in the form of blanching and concentration by evaporation, chances of enzymatic browning was negligible. The browning index was found to increase significantly (P<0.05) during storage in tomato *rasam* paste at both the storage temperatures. However, the changes were more pronounced in the samples kept at 37°C. The optical density (OD) of the product immediately after processing (0 day) was found to be 0.218 which increased to 0.412 and 0.575 in the samples stored for four months at AT and 37°C, respectively. Berry *et al.* (1999) also reported the dark coloration in vegetable curry during storage due to non-enzymatic browning.

Evaluation of PV, FFA and TBA

The rancidity of rasam paste sample was assessed in terms of TBA, FFA and peroxide values. The rancidity parameters indicated the oxidation of fat during storage of food products resulting in off flavour. Table 3 shows the changes in these parameters during storage. At the end of storage, PV of samples was found to increase from an initial value 12.68 to 21.03 Meq of O_2/ Kg at AT and to 25.59 Meq of O_2/ Kg at 37°C. FFA content also increased from an initial value of 0.23 to 3.45% and to 4.26% in AT and 37°C samples, respectively. The initial TBA value of the rasam paste was 0.051 mg Mal/kg of the sample. The increase in TBA value was found to be restricted for initial two months of storage, after wards changes were significant (P<0.05). Increase was higher in samples kept at 37°C which indicated that the higher temperature increased the rate of chemical reactions. Similar trend in PV, FFA and TBA values were reported by Ozogul *et al.* (2005) in European eel. In their study they claimed that initial PV, TBA and FFA values of European eel were 5.28 Meq of O_2/Kg, 0.07 mg Mal/kg and 0.57% of oleic acid, respectively whereas at the end of 12 days storage period the values were reported to increase to 21.6 Meq of O_2/Kg, 0.08mgMal/kg and 1.60% of oleic acid, respectively.

Colour

The changes in colour values in terms of L^* value (lightness), a^* value (redness) and b^* value (yellowness) of tomato rasam paste has been summarised in Table 4. The results of colour values showed that there was decrease in the lightness (L^*) and redness (a^*) while yellowness (b^*) of the paste increased during storage at both the storage temperatures. The L^* value changed from 27.23 to 20.78 and 18.23 for samples stored at AT and 37ºC, respectively. The color a^* value also decreased from 34.29 to 30.02 and to 31.21 in AT and 37ºC samples, respectively. However, the b^* value was increased from 14.52 to 19.51 and to 21.01 in AT and 37ºC samples, respectively. The decrease in a^* value and increase in b^* value might have contributed to the brown colour of the product during storage. The decrease in a^* value and increase in b^* value might have contributed to the brown color of the product during storage. Lycopene is responsible for the red color of tomato products. The decrease in a value may be due to the degradation of lycopene during thermal processing (Boskovic, 1979; Barreiro *et al*., 1997).

Table 5. Changes in sensory characteristics of tomato *rasam* paste (*n*=20)

Storage period (days)	Storage temperature (°C)	Colour	Aroma	Taste	Consistency	OAA
0		8.6a	8.6a	8.5a	8.4a	8.42a
30	28±4	8.4a	8.5a	8.5a	8.4a	8.42a
	37	8.4a	8.5a	8.5a	8.4a	8.39a
60	28±4	8.4a	8.4a	8.4a	8.3b	8.36b
	37	8.4a	8.3b	8.3b	8.2b	8.32b
90	28±4	8.1b	8.2b	8.5b	8.2b	8.00b
	37	8.1b	8.3b	8.1b	8.2b	7.52c
120	28±4	7.9c	8.1b	7.9c	7.9c	7.85c
	37	6.5d	8.0b	7.9c	7.9c	7.00d

Mean values in same column with different letters differ significantly ($P<0.05$)

Sensory evaluation

Sensory evaluation of tomato *rasam* paste was carried out after reconstitution with hot water. The appropriate ratio of *rasam* paste to water was found to be 1:3. The scores for sensory evaluation of *rasam* paste during storage are presented in Table 5. All scores for sensory attributes of the paste were found to decrease during storage at both the storage temperatures. The reduction in the sensory scores during storage may be attributed to the physico-chemical changes of *rasam* paste. The *rasam* paste was found to be darker at the end of four months and it might be due to non-enzymatic browning as discussed in previous section. Product was found to be fairly acceptable even after storage of four months. The overall acceptability of the samples decreased from a score of 8.42 to 7.85 at AT and from 8.42 to 7.00 at 37ºC based on 9-point Hedonic Scale. John *et al.* (1993) claimed good sensory acceptability of raw jackfruit curry stored in pouches for one year. High sensory stability in their product was due to retort processing.

Microbial analyses

The microbiological analyses showed that there was no growth of yeast and molds in the samples during storage. Similar results were also recorded for coliforms. However, at the end of 4th month, total plate count (TPC) was found to be 1.0×10^1 CFU/g in AT samples and 3.0×10^1 CFU/g in 37ºC samples. The stability of the product for duration of four months may be due to the involvement of various hurdles during various processing steps such as lower levels of water activity and pH, and presence of spices and preservative. These hurdles could contribute to inhibit the growth of micro-organisms (Vibhakara *et al.*, 2006).

Conclusions

The ready-to-use tomato *rasam* paste developed in the present study requires tomato in higher proportion which can reduce the tomato wastage. Reduced levels of water activity and pH during processing along with addition of mild preservative could achieve stability in high moisture tomato *rasam* paste after in pack-pasteurization. The product is shelf- stable for four months and could also be scaled up for industrial use. The reconstituted rasam from tomato *rasam* paste could greatly minimize the time required for the conventional preparation of tomato *rasam*. The process is cost effective as well as energy effective. The ethnic nature of the product might motivate self help groups, cottage industries and women entrepreneurs for investments. This may reduce post-harvest losses of tomatoes as well as may fetch high profits to small entrepreneurs.

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