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RESEARCH ARTICLE :

Development of nutrient enriched animal feed from tomato pomace waste under solid state fermentation

H.N. ROJA, R. VEENA, M.B. DARSHAN, K.B. MUNISHAMANNA AND V. PALANIMUTHU

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SUMMARY : Tomato pomace is a mixture of peels, seeds and small amount of pulp with high moisture content that remains after industrial processing. The limitation in utilization of fresh tomato pomace as animal feed is because of its high moisture and fibre contents. Presently, huge quantity of this valuable by product waste is either composted or dumped in landfills, roadsides or rivers leading to environmental hazards. Hence, anexperiment on solid state fermentation industrial processed tomato pomace supplemented with different organic sources (azolla, soybean cake, groundnut cake, maize grits) and fermented by probiotic yeast (*Saccharomyces boulardii*) and lactic acid bacteria (*Lactobacillusplantarum, MTCC 6161)*was studied for the development of nutrient enriched animal feed. The results revealed that tomato pomace supplemented with soybean cake (15%) and combined fermentation by yeast and lactic acid bacteria showed highest protein (23.85%), fat (10.36%), mineral Calcium (1750.0 mg/100 g) and more reduction in fibre (16.69%) compared to other treatments. However, the results clearly indicated that the tomato pomace supplementing with different nitrogen sources and combined fermentation by yeast and bacteria a showed significant enhancement in nutrients with respect to protein, fat, minerals and reduction in the fibre in the fermented tomato pomace which are essential as animal feed supplements. The results conclude that supplementation and fermentation helps to enrich the nutrients in tomato pomace waste which could be a very good source of animal feed supplement.

KEY WORDS :
Tomato pomace, Supplementation, Yeast, Lactic acid bacteria, Nutrient enrichment, Animal feed

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Author for correspondence :
R. VEENA
AICRP on Post Harvest Engineering and Technology, University of Agricultural Sciences, GKVK, BENGALURU (KARNATAKA) INDIA
Email : veenadsc@yahoo.com

See end of the article for authors' affiliations

BACKGROUND AND OBJECTIVES

Huge quantity of fruit and vegetable wastes are generated from processing industry as well as during post harvest chain, which contains various sugars, starch, pectin, minerals and vitamins. These are either composted or dumped in landfills, roadsides or rivers that cause environmental hazards. Efficient management of these wastes will help in preserving vital nutrients of our foods and feeds and brings down the cost of production of processed foods, besides minimizing pollution hazards. Recycling of fruit and vegetable wastes is one of the most important means of utilizing wastes into essential value added products required for human, animal and plant nutrition. Microbial technology is available for recycling and processing of fruit and vegetable wastes through different processes. Fermented potato waste has been successfully tried as animal feed (Anonymous, 2007). According to Naveen *et al*. (2006) fruit waste and byproducts could be used as an alternative feed in livestock rations either as dry product or as silage. Efforts are focused on determining the seasonal availability and nutritive value of locally available fruit and vegetable wastes /by-products to formulate adequate feeding system to bridge the gap between the demand and supply of nutrients of livestock (Anil, 2012).Animals suffer from under feeding and malnutrition due to the shortage of locally produced feeds which are not sufficient to cover the nutritional requirements of the livestock. Therefore, it is necessary that use of unusual food sources like fruit and vegetable wastes, which are not considered as human foods. Food processing wastes such as citrus pulp, tomatoes and grape pomace could be an important part of the diet of ruminants (Alipour and Rouzbehan, 2007).

Tomato (*Solanum lycopersicum* Mill.) is the most important warm season fruit vegetable grown throughout the world mainly China, USA, India, Turkey, Egypt, Italy, Iran, Spain, Brazil and Mexico (FAO, 2011). More than a 33 per cent of this production is grown for the processing industry, which makes tomatoes the world's leading vegetable for processing. Tomato wastes were estimated as 11 million tons, including a little more than 4 million tons of tomato pomace (FAO, 2011; Anonymous, 2010). The tomato fruits are processed for the preparation of products like sauces, pickles, puree, paste, syrup, juice, ketchup etc.After the juice is extracted, a residue tomato pomace, which primarily consists of water, tomato seeds and peels are left. Tomato pomace is often dried and is fed to dairy cows and sheep (Weiss *et al*., 1997) and is relatively rich in protein (17-22%), fat (10-15%), fibre (33-57%), NDF (50-72%) and consists largely of ADF (39-60%) on dry matter basis. Tomato skin have a lower protein and fat content, higher fibre content than pomace (Battaglini and Costantini, 1978 and Knoblich *et al*., 2005). Tomato seeds have a high protein (25-28%), fibre (54% ADF) and fat (20-24%) content on dry matter basis (Persia *et al*., 2003). The role of these wastes as a cheap source of nutrients capable of supplying adequate calories to livestock is very significant. The high moisture and fibre content of this by-product limits its length of storage and direct feeding to animals.

Few studies reviewed on solid state fermentation of apple pomace with *Candida utilis* significantly increased 2.5 fold inprotein content, 3.4 fold in niacin, 1.5 fold in thiamine (Joshi and Sandhu, 1996). Apple pomace fermented with *C. utilis* and *Aspergillus niger*results significant increase in protein content (Bhalla and Joshi, 1994). Supplementing of fruit and vegetable waste with different organic sources like azolla, groundnut cake, soybean cake are known to increase the feed intake and digestibility in cattle (Kusmartono, 2007). Livestock easily digest it, owing to its high protein and low lignin content, azolla could be mixed with concentrates or can be given directly to livestock to poultry, sheep, goats, pigs and rabbits. The limitation in utilization of fresh tomato pomace as animal feed is because of its high moisture and fibre contents. Presently, huge quantity of this valuable by product waste is either composted or dumped in landfills, roadsides or rivers leading to environmental hazards. An alternative to such disposal methods could be recycling of this waste through solid state fermentation technology (Pandey, 2003) for developing animal feed supplements. This approach would also help in proper utilization of tomato culled fruit wastes which are otherwise discarded.

RESOURCES AND METHODS

Collection of industrial processed tomato pomace for experiment :

Industrial processed tomato pomace was available in plenty during the season (April – August) at SAFAL unit of Mother Dairy (National Dairy Development Board), near Whitefield, Bengaluru. The processed fresh tomato pomace waste was collected from the mother dairy processing plant and stored in a cold room temperature of 3 – 5º C for the experimental studies (Plate A).

Plate A : SAFAL Fruit and vegetable industrially processed Tomato pomace Processing Unit@ Whitefield

The experiment was conducted at All India Coordinated Research Project of Post Harvest Engineering Technology Scheme, University of Agricultural Sciences, GKVK, Bengaluru. The experiment was conducted to develop a nutrient enriched feed from tomato pomace waste by supplementing with different organic sources under solid state fermentation using yeast (*Saccharomyces boulardii*) and lactic acid bacteria (*Lactobacillus plantarum*, MTCC 6161).The experiment was conducted with a Completely Randomized Design (CRD) with 10 treatments and replicated thrice (Plate B) with following treatment details are as follows:

Treatments	Description
T_1	Tomato pomace (control)
T_2	TP (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)+Yeast
T_3	TP(60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%) + Yeast
T_4	TP(60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%) + Yeast
T_5	TP (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)+ LAB
T_6	TP (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%) + LAB
T_7	TP (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%) + LAB
T_8	TP (60%) +Azolla (15%) + Maize (15%) + Rice polish (10%)+ Yeast and LAB
T_9	TP (60%)+Groundnut cake (15%) + Maize (15%) + Rice polish (10%)+ Yeast and LAB
T_{10}	TP (60%) +Soybean cake (15%) + Maize (15%) + Rice polish (10%)+ Yeast and LAB

Yeast: *Saccharomyces boulardii;* LAB: *Lactobacillus plantarum*

Plate B : Solid State Fermentation of tomato pomace supplemented with different organic sources

Preparation of tomato pomace waste supplemented with different organic sources for solid state fermentation :

The industrially processed tomato pomace of 1.2 (60%) kg weight with a moisture content (excess moisture drained out manually) about 50 per cent was placed in autoclavable polythene bags of 400 gauge and different organic sources *viz.*, azolla (15%), soybean cake (15%), groundnut cake(15%), maize (15%), rice polish (10%) were supplemented to the tomato pomace as per the different treatments and subjected for pasteurization (heat treatment at 115^0 C) under autoclave for removal / reduction of anti-nutritional factors. After heat processing, the bags containing tomato pomace with different treatments were inoculated with microbial broth cultures of yeast *S boulardii* and lactic acid bacteria *L. plantarum* (MTCC 6161) (Plate C) containing 10^7 cfu / ml at 5 per cent inoculums as per the treatments. The bags were completely air tighten by sealing the bags and sealed bags were kept for incubation at 30^0 C for yeast and 37^0 C LAB inoculated bags for 6 days under solid state fermentation.

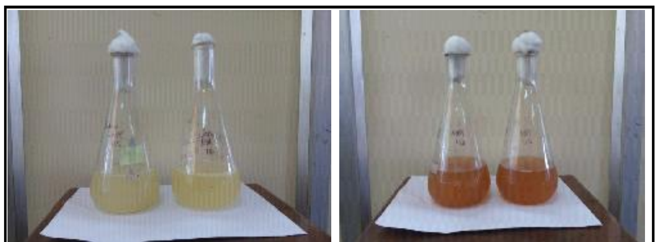

Plate C : Broth cultures of *S. boulardii* and *L. plantarum*

Supplementing different organic sources to tomato pomace waste Azolla :

Azolla (*Azollapinneta*) is aquatic fern and is a good source of protein and it contains all essentialamino acids, minerals such as iron, calcium, magnesium, potassium, phosphorus, manganese etc. apart from appreciable quantities of vitamin A precursor beta-carotene and vitamin B_{12}(Cherry *et al.*, 2014). Fifteen per cent of azolla was supplemented to the tomato pomace wherever it is required in the treatments.

Groundnut cake:

Groundnut (*Arachis hypogaea* L.) is an important source which provides an inexpensive source of high quality dietary protein and oil.Groundnut protein is increasingly becoming important as food and feed sources

(Ayoola *et al.*, 2012). Fifteen per cent of groundnut cake was supplemented to the tomato pomace wherever it is required in the treatments.

Soybean cake:

Soybean (*Glycine max* L.) is a significant and cheap source of protein for animal feeds and many packaged meals. It also have high contents of dietary fiber, iron, manganese, phosphorus and also several vitamins. Fifteen per cent of soybean was supplemented to the tomato pomace wherever it is required in the treatments.

Maize:

Maize (*Zea mays* L.) grain has great nutritional value, with high levels of starch and also valuable proteins and oilsand also can be used as raw material for manufacturing many industrial products (SuleEnyisi *et al.*, 2014). Fifteen per cent of maize was supplemented to the tomato pomace wherever it is required in the treatments.

Rice polish:

Rice polish is derived from the outer layers of the rice caryopsis during milling and is the cheapest source of energy and protein for poultry feeding. It is a good source of protein, fat, carbohydrate, fibre and vitamins and minerals (Hossain *et al.*, 2012). Ten per cent of rice polish was supplemented to the tomato pomace wherever it is required in the treatments.

Tray drying:

After completion of 6 days fermentation, the samples were subjected to tray drying at 50-55°C for 48 hours.

Plate D : Tray drying of fermented tomato pomace

Samples were spread uniformly in the tray for effective drying (Plate D).

Grinding:

Tray dried samples were grinded in mixer/grinder to get powder and grounded powder samples were packed in polythene bags and stored under low temperature. The stored samples were subjected for biochemical, proximate contents and minerals analysis by following standard procedures.

The samples were subjected for biochemical parameters, proximate composition and minerals by following standard methods (AOAC, 2005)

pH:

The pH of fermented tomato pomace samples was measured using digital pH meter of analog model (Sadasivam and Manickam, 1996).

TSS:

Total soluble solid (TSS) was measured using ERMA hand refractometer having a range of 0-35^{0} Brix at room temperature. One or two drops of the sample were placed on the hand refractometer and total soluble solids was measured and expressed in degree Brix (AOAC, 1995).

Titrable acidity:

Ten grams of sample was taken in a 100 ml beaker and boiled in water bath at 70ºC for one hour then cooled and transferred to 100 ml volumetric flask and make upto 100 ml, later, filtered with Wattmann No. 4 filter paper. From this 10 ml of aliquot was taken in a 100 ml conical flask and titrated against 0.1 N NaOH using one or two drops of Phenolphthalein indicator. Appearance of light pink colour denoted the end point. Total titrable acidity was expressed as per cent citric acid. Proximate contents of moisture, protein, fat, fibre, ash and carbohydrate were determined as per AOAC, 2005 methods.

Energy:

Energy was computed as followed for all the samples given by AOAC (1995).

Energy (kcal) = [Protein (g) x 4] + [Carbohydrate (g) x 4] + [Fat (g) x 9]

Minerals:

The mineral solution was prepared by dissolving the ash obtained fromsamples in muffle furnace using diluted hydrochloric acid (6N) (AOAC, 2005).

Estimation of calcium, magnesium, phosphorus and iron :

Mineral solution was prepared from the ash of tomato pomace powders and were fed to the AAS (Atomic Absorption Spectrophotometer) having appropriate hallow cathode lamps. After getting values for standard solutions, amount of each element was calculated using the equation (AOAC, 2005).

Statistical analysis :

Statistical interpretation of data was done by following the Fischer's analysis of variance technique as given by Panse and Sukhatme (1967). The results were computed at five per cent level of significance. Critical differences were worked out whenever F test was significant using Duncan's multiple range test.

OBSERVATIONS AND ANALYSIS

The industrial processed tomato pomace supplemented with different organic sources and fermented by selective yeast (*Saccharomyces boulardii*) and LAB (*Lactobacillus plantarum*) under solid state fermentation for nutrient enrichment was studied. The**c**hanges in biochemical, proximate composition, minerals by the influence of supplementation and fermentation are discussed here under.

Changes in pH, TSS and titrable acidity of the fermented tomato pomace as influenced by supplementation and fermentation is presented in Table 1 :

pH:

The initial pH of the tomato pomace was 5.27, when it was supplemented with different organic sources, the pH varied from 4.88 to 5.27 between the treatments. After 6 days of fermentation by yeast and LAB, the change in pH varies from 4.13 to 4.24 between treatments. The slight variation in pH among the different treatments is due to the fermentation potential of the microorganisms. Fermentative activity of both yeast and LAB reduced the pH level compared to un-inoculation, mainly due to the utilization of sugars and carbohydrates in the substrate. Among yeast fermentation, the highest reduction of pH (4.18) was more in supplementing with 15% groundnut cake. Similarly, LAB fermentation of tomato pomace supplemented with 15% soybean cake showed higher reduction in pH (4.13).The combined fermentation of tomato pomace supplemented with different organic sources did not influenced significantly on reduction of pH over single inoculation. However, higher reduction was observed by dual inoculation in all the three organic sources. This may be due to the pH depends upon the acids and sugars utilized by the micro-organisms in the supplementing substrates and thus improving tomato pomace preservation. These results support the work of Mc Donald *et al*. (2002) in sweet sorghum silage.

Total soluble solids:

The results revealed that the initial TSS of the tomato pomace was 2.33 ^{0}Brix, when it was supplemented with different organic sources the TSS varied from 2.23 to 3.03 ^{0}Brix. After 6 days of fermentation by yeast and LAB, the TSS varies from 1.10 to 1.53 ^{0}Brix between treatments. Reduction in TSS is due to high fermentative character of the yeast than lactic acid bacteria. Utilization of sugar is indicative of growth and fermentative efficiency of the yeast and lactic acid bacteria. The results revealed that the lowest TSS (1.10 ^{0}Brix) was observed in the tomato pomace supplemented with 1% azolla and fermented by yeast (T_2). Supplementing with 15% azolla has further enhanced the yeast activity during fermentation which helps in higher utilization of sugars their by more reduction in pH. Similarly, LAB and combined fermentation of supplemented tomato pomace showed less fermentation efficiency compared to yeast fermentation.

Titrable acidity:

The initial titrable acidity of the tomato pomace was 0.73 per cent. After 6 days fermentation by Yeast and LAB, the titrable acidity varied from 1.00 to 1.98 per cent between the treatments.The results revealed that the highest titrable acidity was observed in the tomato pomace supplemented with 15% soybean cake (T_4 : 1.31%) and 15% groundnut cake (T_6 : 1.98%) by single inoculation.Combined fermentation of supplemented tomato pomace did not influenced much on the enhancement of titrable acidity in any of the organic sources. However, LAB fermented supplemented with 15% groundnut cake (T_6) showed highest titrable acidity compared to other supplements. Upon fermentation of supplemented tomato pomace, production of titrable acidity in terms of lactic acid was more important in the fermented products.

Changes in crude protein and fat of the fermented tomato pomace as influenced by supplementation and fermentation is presented in Table 2 (Fig. 1) :

Crude protein:

The initial protein content of the control tomato pomace was 18.31 per cent. After 6 days fermentation by yeast and LAB, the protein content varied from 18.84 to 23.85 per cent between the treatments. The increase in the protein content of tomato pomace is due to utilization of sugars and organic sources by the probiotic yeast and LAB. The highest crude protein was observed in the tomato pomace supplemented with 15% soybean cake in both individual and combined fermentation by yeast and LAB strains (T_4: 22.95%, T_7: 23.22% and T_{10} : 23.85%).Combined inoculation of Yeast and LAB showed more increase in the protein content compare to individual inoculation of tomato pomace. Tomato pomace supplemented with 15% soybean cake in individual and also by combined inoculation enriched the protein content of tomato pomace compare to the other organic supplements.Among three different sources of nitrogen, tomato pomace supplemented with soybean cake and combined fermentation is greatly influenced on enhancement of protein compared to azolla and groundnut cake supplementation (Table 1 and Fig. 1). These results support the work of Hong *et al.* (2004) who reportedthat fermented soybeans and fermented soybean meals contained 10% more crude protein than raw soybeans and soybean meals.

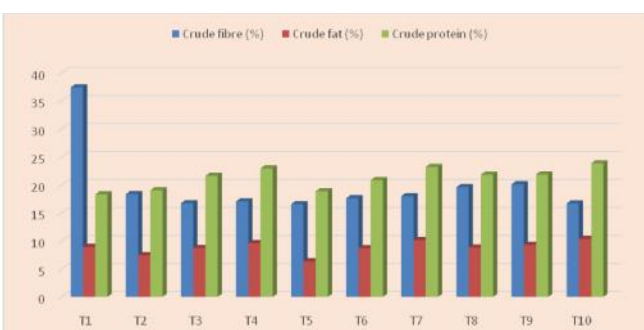

Fig. 1 : Changes in crude fibre, crude fat and crude protein of the fermented dried tomato waste as influenced by supplementation and fermentation

Crude fat:

The initial fat content of the tomato pomace was 8.94 per cent. After 6 days fermentation by yeast and LAB fermentation, the fat content varied from 6.33 to 10.36 per cent between the treatments. The tomato pomace supplemented with 15% soybean cake showed highest crude fat content in both individual fermentation of yeast (T_4 : 9.59%) and LAB (T_7 : 6.13%) (Fig 1). Similarly combined fermentation of tomato pomace supplemented with 15% soybean cake also showed highest fat content (T_{10} : 10.36%). The tomato pomace supplemented and fermented with combination of both yeast and LAB strains showed better enhancement in fat content. The organic sources enriched the crude fat content of the inoculated tomato pomace. This may be due to the addition of sugars and carbohydrates by micro-organisms in the organic substrates which helps in enhancing the crude fat. The increase in fat content of the fermented tomato pomace sample may be due to the fact that the micro-organisms which degrade the sample as well as microbial biomass as reported by Odetokum, 2000 in mango peel. Among three different sources of nitrogen, tomato pomace supplemented with soybean cake is more influenced on enhancement of fat content either by single or combined inoculation compared to azolla or groundnut cake supplementation (Table 2).

Changes in crude fibre and ash of the fermented dried tomato pomace waste as influenced by supplementation and fermentation is presented in Table 3 :

Crude fibre:

The initial fibre content of the tomato pomace was 38.11 per cent. When supplemented with different sources, fibre content varied from 31.20 to 36.62 per cent between the treatments before fermentation. After 6 days of fermentation by yeast and LAB, the fibre content varied from 16.56 to 20.12 per cent between the treatments.The highest reduction of fibre was observed in tomato pomace supplemented with 15% groundnut cake (T_3 : 16.72%) by yeast fermentation compared to LAB fermentation (Fig. 1). Among LAB fermentation, the tomato pomace fermented with 15% azolla recorded highest fibre reduction (T_5 : 16.56%).The combined fermentation of tomato pomace supplemented with 15% soybean cake showed highest fibre reduction compared to other organic supplements.However, crude fibre reduction is more in the yeast compared to LAB and combined inoculation of tomato pomace supplemented with different organic sources. This might be attributed to the fact that during fermentation carbohydrate including cellulose, pectin, lignocellulose and starch are broken down by fermenting micro-organisms thereby reducing the fibre content (Raimbault and Tewe, 2001).

Ash:

The initial ash content of tomato pomace was 2.80 per cent. The ash content varied from 6.26 to 8.92 per cent between the treatments after 6 days of fermentation by Yeast and LAB. Both yeast and LAB fermentation of tomato pomace supplemented with 15% azolla recorded higher ash content (T_2 : 8.92% and T_5 : 8.82%) compared to other organic supplements. Also in case of combined fermentation of tomato pomace supplemented with 15% azolla showed highest ash content (T_8 : 8.80%). Among three different organic sources, azolla with combined inoculation is more influenced on ash

Table 1 : Changes in pH, TSS and Titrable acidity of the fermented tomato pomace waste as influenced by supplementation and fermentation

Yeast / Lab fermentation	Treatment details	pH		TSS (^{0}Brix)		Titrable acidity (%)
		Before fermentation	After fermentation	Before fermentation	After fermentation	
	T_1 = Tomato pomace (control)	5.27[a]	5.13[a]	2.33[b]	1.80[a]	0.73[e]
Yeast fermentation	T_2 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	4.94[b]	4.24[b]	2.47[b]	1.10[b]	1.23[cd]
	T_3 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.92[b]	4.18[b]	2.37[b]	1.47[ab]	1.26[cd]
	T_4 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.90[b]	4.21[b]	2.23[b]	1.43[ab]	1.31[cd]
Lab fermentation	T_5 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	4.91[b]	4.20[b]	2.37[b]	1.30[b]	1.48[c]
	T_6 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.90[b]	4.19[b]	2.47[b]	1.50[ab]	1.98[a]
	T_7 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.94[b]	4.13[b]	2.60[ab]	1.47[ab]	1.82[ab]
Yeast and Lab fermentation	T_8 = Tomato pomace (60%) +Azolla (15%) + Maize (15%) + Rice polish (10%)	4.94[b]	4.21[b]	2.93[a]	1.50[ab]	1.00+
	T_9= Tomato pomace (60%)+Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.88[b]	4.16[b]	3.00[a]	1.50[ab]	1.58[bc]
	T_{10}=Tomato pomace (60%) +Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.88[b]	4.15[b]	3.03[a]	1.53[ab]	1.39[c]
S.E. ±		0.04	0.06	0.14	0.13	0.06
C.D. (P=0.05)		0.13	0.18	0.42	0.39	0.17

Note: Fermentation period 7 days, Yeast*: Saccharomyces cerevisiae*, LAB: *Lactobacillus plantarum*

Table 2 : Changes in protein and fat of the fermented tomato waste as influenced by supplementation and fermentation

Yeast / Lab fermentation	Treatment details	Protein (%)	Fat (%)
	T_1 = Tomato pomace (control)	18.31[f]	8.94[bc]
Yeast fermentation	T_2 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	19.04[e]	7.46[d]
	T_3 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	21.62[c]	8.74[c]
	T_4 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	22.95[b]	9.59[ab]
Lab fermentation	T_5 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	18.84[ef]	6.33[e]
	T_6 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	20.84[d]	8.72[c]
	T_7 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	23.22[ab]	10.13[a]
Yeast and Lab	T_8 = Tomato pomace (60%) +Azolla (15%) + Maize (15%) + Rice polish (10%)	21.85[c]	8.81[bc]
fermentation	T_9= Tomato pomace (60%) +Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	21.88[c]	9.32[bc]
	T_{10}=Tomato pomace (60%) +Soybean cake (15%) + Maize (15%) + Rice polish (10%)	23.85[a]	10.36[a]
S.E.±		0.13	0.11
C.D. (P=0.05)		0.40	0.34

Note: Fermentation period 7 days, Yeast*: Saccharomyces cerevisiae*, LAB: *Lactobacillus plantarum.*

enhancement in the tomato pomace. This may be due to the addition of minerals in terms of ash present in the supplemented organic sources degraded by both yeast and bacterial fermentation helps in enhancement of ash content.

Changes in moisture, carbohydrates and energy values of the fermented tomato waste as influenced by supplementation and fermentation is presented in Table 4 :

Moisture:

The initial moisture content of tomato pomace was 4.13 per cent. The moisture content of fermented tomato pomace varied from 4.17 to 4.69 per cent after 6 days of fermentation by yeast and LAB fermentation with different nitrogen sources.In the present study, the results indicated that moisture content did not much vary between the treatments. However, the tomato pomace supplemented with organic sources of groundnut cake and azolla showed slight more in moisture content compared to soybean cake fermented by single or combined inoculation of yeast and LAB fermentation which are non-significant each other. More moisture in the tomato pomace supplemented with organic sources may be due to the additional moisture present in the supplemented sources of groundnut cake and azolla.

Carbohydrate:

The initial carbohydrate content of tomato pomace was 28.39 per cent. The carbohydrate content in the

Table 3 : Changes in fibre and ash of the fermented dried tomato pomace waste as influenced by supplementation and fermentation

Yeast / Lab fermentation	Treatment details	Fibre (%)		Ash (%)
		Before fermentation	After fermentation	
	T_1 = Tomato pomace (control)	38.11[a]	36.43[a]	2.80[e]
Yeast fermentation	T_2 = TP(60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	33.27[e]	18.36[c]	8.92[a]
	T_3 = TP(60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	31.20[g]	16.72[e]	6.84[bc]
	T_4 = TP (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	35.38[c]	17.06[de]	7.06[bc]
Lab fermentation	T_5 = TP (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	34.28[d]	16.56[e]	8.82[a]
	T_6 = TP (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	32.27[f]	17.62[cde]	6.48[cd]
	T_7 = TP (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	35.96[c]	18.00[cd]	6.26[d]
Yeast and Lab	T_8 = TP (60%) +Azolla (15%) + Maize (15%) + Rice polish (10%)	33.37[e]	19.60[b]	8.80[a]
fermentation	T_9= TP (60%)+Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	31.48[g]	20.12[b]	7.31[b]
	T_{10}=TP (60%) +Soybean cake (15%) + Maize (15%) + Rice polish (10%)	36.62[b]	16.69[e]	7.02[bc]
S.E. ±		0.20	0.23	0.09
C.D. (P=0.05)		0.60	0.67	0.26

Note: Fermentation period 7 days, Yeast*: Saccharomyces cerevisiae*, LAB: *Lactobacillus plantarum.*

Table 4 : Changes in moisture, carbohydrates and energy values of the fermented tomato waste as influenced by supplementation and fermentation

Yeast / Lab fermentation	Treatment details	Moisture (%)	Carbohydrates (%)	Energy (K cal)
	T_1 = Tomato pomace (control)	4.13[a]	28.39[d]	220.56[f]
Yeast	T_2 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	4.62[a]	41.61[b]	249.06[e]
fermentation	T_3 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.50[a]	41.58[b]	268.23[bc]
	T_4 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.39[a]	38.95[c]	272.01[abc]
Lab	T_5 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	4.41[a]	44.71[a]	248.24[e]
fermentation	T_6 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.64[a]	41.70[b]	266.09[c]
	T_7 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.45[a]	37.94[c]	274.66[ab]
Yeast and	T_8 = Tomato pomace (60%) +Azolla (15%) + Maize (15%) + Rice polish (10%)	4.54[a]	37.40[c]	257.03[d]
Lab	T_9= Tomato pomace (60%)+Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	4.69[a]	36.67[c]	259.54[d]
fermentation	T_{10}=Tomato pomace (60%) +Soybean cake (15%) + Maize (15%) + Rice polish (10%)	4.17[a]	37.86[c]	278.35[a]
S.E.±		NS	0.46	1.19
C.D. (P=0.05)			1.36	3.50

Note: Fermentation period 7 days, Yeast*: Saccharomyces cerevisiae*, LAB: *Lactobacillus plantarum* fermented tomato pomace is varied from 36.67 to 44.71 per cent between the treatments after 6 days of fermentation by yeast and LAB strains. The results indicated that the tomato pomace supplemented with 15% azolla fermented by single inoculation of yeast and LAB showed highest carbohydrate content (T_2 : 41.61%) and (T_5 : 44.71%), respectively. Combined fermentation of tomato pomace supplemented with 15% soybean cake showed highest carbohydrate content (T_{10} : 37.86%).The results indicated that inoculated tomato pomace with organic supplements enriches the carbohydrate. Combined fermentation of tomato pomace supplemented with groundnut cake (T_9)showed lowest carbohydrate (36.67%), followed by T_8 (37.40) and highest carbohydrate was recorded (37.86%) in T_{10}. The results indicated that the carbohydrate content in fermented tomato pomace is not much influenced by Yeast or LAB fermentation. The results agrees with the statement of Odetokum (2000) who reported that increase in carbohydrate content during fermentation may be due to a reduction in the fibre content and increase in both reducing sugars and total soluble sugars. This may also be attributed to the fact that during fermentation carbohydrate including cellulose, pectin, lignocellulose and starch are broken down by fermenting micro-organisms thereby reducing the fibre content (Raimbault and Tewe, 2001).

Energy:

The initial value of energy of tomato pomace was 220.56 k cal. The energy values varied from 248.24 to 278.35 kcal between the treatments after 6 days of fermentation and supplementation.Yeast fermentation of tomato pomace with soybean cake (T_4) recorded higher energy value (272.01 kcal) which is significantly differ from treatments T_3 (268.23 kcal) and T_2 (249.06 kcal) indicating that supplementing of organic source soybean cake is more influenced on energy of tomato pomace by Yeast fermentation.In the present study, both individual and combined inoculation of tomato pomace with yeast and LAB, tomato pomace supplemented with 15% soybean cake showed highest energy content (T_4 : 272.01 kcal), (T_7 : 274.66 kcal) and (T_{10} : 278.35 kcal), respectively compared to tomato pomace supplemented 15% groundnut cake and 15% azolla.Among three different sources of nitrogen supplementing to tomato pomace with soybean is more influenced in energy by either single or combined inoculation of Yeast and lactic acid bacteria.

Changes in mineral content of the fermented tomato pomace as influenced by supplementation and fermentation are presented in Table 5 :

Table 5 : Changes in mineral contents of the fermented tomato waste as influenced by supplementation and fermentation

Yeast / Lab fermentation	Treatment details	Minerals (mg/100g)			
		Ca	Mg	P	Fe
	T_1 = Tomato pomace (control)	405.00^f	260.00^h	91.00^d	12.00^f
Yeast fermentation	T_2 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	1615.00^d	503.33^b	326.67^a	25.67^e
	T_3 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	1535.00^e	330.00^c	175.00^c	32.33^c
	T_4= Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	1641.67^{cd}	271.61^g	185.00^c	28.33^{de}
Lab fermentation	T_5 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	1651.67^c	535.00^a	295.00^b	35.67^b
	T_6 = Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	1623.33^d	323.67^d	175.00^c	31.33^c
	T_7 = Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	1726.67^{ab}	280.00^f	182.33^c	26.67^e
Yeast and Lab fermentation	T_8 = Tomato pomace (60%) + Azolla (15%) + Maize (15%) + Rice polish (10%)	1703.33^b	540.00^a	320.00^a	39.00^a
	T_9= Tomato pomace (60%) + Groundnut cake (15%) + Maize (15%) + Rice polish (10%)	1630.00^{cd}	331.67^c	188.33^c	33.00^{bc}
	T_{10}=Tomato pomace (60%) + Soybean cake (15%) + Maize (15%) + Rice polish (10%)	1750.00^a	313.33^e	190.00^c	30.33^{cd}
S.E. ±		8.35	2.74	7.74	0.54
C.D. (P=0.05)		24.63	8.08	22.84	1.61

Note: Fermentation period 7 days, Yeast*: Saccharomyces cerevisiae*, LAB: *Lactobacillus plantarum.*

The calcium content in the control tomato pomace was 405 mg/100g. After 6 days of fermentation and supplementation, the calcium content varied from 1535.00 to 1750.00 mg/100g between treatments.The highest Ca (1641.67 mg/100g) content was observed in the tomato pomace supplemented with 15% soybean cake and the highest Mg (503.33 mg/100g), P (326.67mg/100g) and Fe (28.33mg/100g) content was recorded in the tomato pomace supplemented with 15% azolla by yeast fermentation. The combined fermentation of tomato pomace with yeast and LAB showed highest Mg (535.00mg/100g), P (295.00 mg/100g) and Fe (35.67mg/100g) content with supplemented 15% azolla.

The mineral composition of the tomato pomace by supplementation and fermentation significantly enhanced with respect to Ca, Mg, P and Fe minerals over un-inoculated control treatment. The increase in mineral content of tomato pomace may be due to addition of organic supplementsand fermentation helps in enhancement of mineral content. Similarly, Oyewole and Odunfa (1989) reported that fermentation process caused an increase in the concentration of calcium (+12%) in cassava but reductions in the levels of potassium (-71%), sodium (-68%) and manganese (-60%). The developed nutrient enriched feed from tomato pomace waste using yeast and lactic acid bacteria under solid state fermentation in the form of flakes and powder is shown in Plate 1.

Plate 1 : Nutrient enriched feed from tomato pomace in the form of flakes and powder

Conclusion :

Tomato pomace is a mixture of peels, seeds and small amount of pulp with high moisture content that remains after industrial processing. The limitation in utilization of fresh tomato pomace as animal feed is because of its high moisture and fibre contents. Presently, huge quantity of this valuable by product waste is either composted or dumped in landfills, roadsides or rivers leading to environmental hazards. Hence, an attempt was made an alternative to such disposal methods could be recycling of this waste through solid state fermentation technology for developing nutritionally enriched feed from this waste for livestock as feed supplement.

Fermentation helps to increase protein, fat, minerals and reduction in fibre in the tomato pomace thus improving its nutritional quality. Tomato pomace can be used as a raw material for the production of animal feed through solid state fermentation by yeast and lactic acid bacteria. Microbial processing of tomato pomace waste into animal feed would help in proper utilization of this waste which otherwise being discarded.

Authors' affiliations :
H.N. ROJA, M.B. DARSHAN, K.B. MUNISHAMANNA AND V. PALANIMUTHU, AICRP on Post Harvest Engineering and Technology, University of Agricultural Sciences, GKVK, BENGALURU (KARNATAKA) INDIA
Email : darshandachan@gmail.com; shamannabyrappa@gmaili.com; re.uas.blore@gmail.com

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