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Effects of drying methods on physico-chemical qualities of phytoingredients treated dry meat balls (PORK) during storage

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Abstract
A study was conducted to investigate the effect of drying methods on various qualities and shelf-life of dry pork balls treated with phytoingredients (*viz.* Amla, Carrot, Round lemon, Mint, and Pomegranate). The temperature maintained for Oven-drying was 60°C while for solar drying temperature was maintained between 55-60°C. For both the drying methods there were control and treatment groups which were further packaged by aerobic and vaccum packaging method. In the treatment groups phytoingredients were added along with cured meat, spices and condiments whereas phytoingredients and other non-meat ingredients were absent in control group. The products were kept at room temperature and changes were observed during storage up to six months. Due to addition of phytoingredients there were certain changes in the proximate composition of the dry products. TBARS values of the samples were affected due to antioxidant contents of the phytoingredients. The solar-dried samples had higher acceptability level than the oven-dried samples. The results were attributed to the various changes that occurred during the drying process. Solar-drying could be applied to produce hygienic pork products under hot and humid climatic environment over mechanical drying.

Keywords: Dry meat balls, phytoingredients, oven-drying solar-drying, storage periods

Introduction
Preservation methods of meat mainly include use of low or high temperatures, reduction of water contents (activity) or adoption of chemical preservatives. Among the many preservation methods, dehydration or drying is probably one of the earliest and most effective methods developed (Hotchkiss, Potter; 1995) [9]. Open air sun-drying process which involves exposing pieces of meat to open air and sunlight has a lot of disadvantages over oven-drying; as such meat pieces can be exposed to dust, rain, insects which contribute to non-acceptability of the meat. Drying in the open air is a common phenomenon in developing countries and the effects need to be examined.

The most common form of chemical deterioration of meat is oxidative rancidity. Lipid oxidation can have negative effects on quality of meat and meat products causing changes in sensory attributes (colour, texture, odour and flavour) and nutritional quality (Decker *et al*., 1996; Rababah *et al*., 2004) [5, 16]. To reduce lipid oxidation antioxidants are used in meat and meat products. The antioxidants can be synthetic or natural origin (Attmann *et al*, 1986; Powell *et al*, 1986) [4, 15]. But the demand for natural antioxidants, especially of plant origin has been increased in the recent years due to the growing concern among consumers about these synthetic antioxidants because of their potential toxicological effects (Juntachote *et al*., 2006; Naveena *et al*., 2008; Gonzalez *et al*., 2008) [10, 12, 8]. The addition of antioxidants during packing of dried meat in the manner that eliminates oxygen and moisture prevent mould and fungus growth (Forrest *et al*., 1975) [7].

Among the conventional meats, pork is the most popular in the tribal societies of North Eastern Region (NER) of India. Diet atlas of the people of North Eastern Region (NER) when looked into indicates that more than 90% of the indigenous people are non-vegetarian against the national average of 70% and pig is considered as an animal of choice because of natural attraction of our local tribal people towards the avocation of pig rearing. Pork is consumed not only as a source of diet in NER but also occupies places in various religious and social festivals.

NER has the highest pig population in the country and thus pork consumption is also one of the highest.

Considering the disadvantages of conventional drying methods and perennial deficiency of electrical energy in the NER, it would be worthwhile if some alternative methods of drying be evolved and practiced in rural areas for drying of meat/ pork. The abundant untapped solar energy can efficiently and purposefully be used among the energy deficient rural areas of the region. This work was therefore designed to evaluate the effects of phytoingredients on certain physico-chemical properties of meat balls (pork) dried by oven-drying and solar-drying methods in order to recommend the better method of drying for adoption by the people of NER with regards to hygienic production of dry meat products.

Materials and Methods

Sample preparation

Fresh cuts of pork were collected just after slaughter from nearby local market (Beltola market, Guwahati). After separation of fat and skin, deboning of lean meat was done manually maintaining hygienic condition in the laboratory. After mincing, minced meat was mixed thoroughly with sodium chloride (2 per cent), sodium nitrite (0.02 per cent) and kept at refrigerated temperature (4±1°C) for 24 hours to accomplish the process of curing. After curing meat emulsion was prepared with addition of non meat ingredients which includes phytoingredients *viz*. Amla (*Emblica officinalis*), Carrot (*Daucus carota*), Round lemon (*Citrus limon*), Mint (*Mentha sachalinnsis*), and Pomegranate (*Punica granatum*) in 1:3.5:1:1:3.5 ratio and spices (onion, garlic and ginger paste, black pepper, and cumin, coriander powder, cinnamon, clove and paprika). Ice cubes were also added. From the meat emulsion meat balls were prepared manually.

Drying

After preparation of the meat balls they were placed in solar dryer as well as mechanical dryer. The identities of each group were maintained and their weights were recorded. The temperature maintained in the mechanical dryer was 60°C but the temperature in solar dryer was maintained between 55-60°C (due to fluctuation of temperature in the solar dryer). The time required to dry the meat balls were 40-45 hours in the solar dryer whereas in mechanical dryer the time required was 36-38 hours. Along with the treated samples one control sample was also prepared without addition of antioxidative property possessing phytoingredients.

Packaging

The products were packed in food grade HDPE packaging material and were kept in room temperature by maintaining their identity. The samples were assessed at intervals to determine the quality parameters.

Proximate Composition

The Moisture, Crude Protein (CP), Ether Extract (EE) and Total Ash (TA) of the products of the control and the treated groups were estimated as per the standard procedure laid down by the AOAC, 1970 [3].

Measurement of Water activity

Water activity of the control as well as treated groups was measured by a water activity meter of Aqua Lab (Dew point water activity meter 4TE).

Thiobarbituric Acid Reactive Substance (TBARS) value

The TBARS value was determined as per the method of Witte *et al*. (1970) [20].

Sensory Evaluation of the rehydrated pork cubes

Ready to eat dry meat products were subjected to evaluation for organoleptic qualities by serving the products to a 7-member panel of semi trained judges of different age group and sexes. Dried meat balls were rehydrated according to the method of Ranganna, 1986 [17] for consumption.

Statistical analysis

A minimum of five batches of the products were prepared for the proposed study. The data obtained from the above study were analysed statistically by a software SAS (SAS 9.3 software).

Results and Discussions

Proximate Composition of Meat Balls

The results pertaining to proximate composition of dry pork balls are presented in Table: 1, 2, 3 and 4.

There is a significantly ($p<0.01$) increasing trend in moisture content from 0 to 180 days in all the samples during storage period kept in aerobic packaging method. But in vacuum packaged products no significant differences were observed. The study showed that the moisture content remain unaffected by the drying methods but during storage moisture content was found to be higher in mechanically dried products. The vacuum packaging interfered in moisture exchange from the environment and therefore, better product quality could be obtained because in aerobic packaging as storage period increased moisture content was also increasing. Due to use phytoingredients the products (treatment group) contained more moisture due to their high moisture content which might have added to the total moisture content of the products.

The dry products have a tendency to absorb moisture from the atmosphere. There are structural and cellular changes in the dry products due to disruption of dry products making space for water molecule to absorb. This increase in moisture may be as a result of variation of the storage temperature and relative humidity. These findings are supported by the works of Ajiboye *et al*., 2011 [1], who reported that during storage of dry meat moisture content increased significantly.

There is a decreasing trend in percent of protein in all the products as the storage period of products increased in meat balls kept in aerobic packaging. But in vacuum packaged products no significant differences were observed. The control group contained more protein than that of treated groups due to absence of non meat ingredients. The non meat ingredients which contains the phytoingredients containing lower amount of protein, so might have added to lower protein content than that of control group. The overall protein percent was significantly lower in all the stored samples.

The moisture might influence the protein percentage. This is in agreement with the findings of Ockerman (1985) [13] who reported that as the moisture content of meat increased, protein and dry matter contents decreased reciprocally. Another reason might be due to breakdown of protein during storage of the products due to enzymatic action of microbes. This study is supported by the findings of Akhter *et al*. (2009) [2] who also observed decrease in protein content during storage of meat dried by sun and oven drying.

There are no effects on the fat contents of the products due to drying methods could be seen. There were significant differences ($p<0.01$) between the control and treatment

groups in all the drying methods which might be due to the presence of non meat ingredients in the treatment groups because the phytoingredients contains a minor amount of fat. The fat content is higher in the control groups than treated groups due to absence of non meat ingredients. There was a significantly decreasing trend observed in the control and treatment groups in the storage period from 0 to 180 days in both solar and mechanically dried products kept in aerobic packaging which might be due to slight lipolysis that occurred in aerobic packaged products. But in vacuum packaged products no significant differences were observed. As meat ages the fat deteriorates through microbial attack and tissue enzyme activity which causes the development of free fatty acid and oxidation of unsaturated fatty acids. Free Fatty Acid values in meat progressively increases with storage time (Pearson, 1968) [14]. This study is supported by the findings of Akhter *et al*., 2009 [2] who also observed decrease in fat content during storage of meat dried by sun and oven drying.

Within the solar and mechanical drying systems, there are no significant differences in ash content. However, differences were observed between the control and treated groups. The percentage of ash were higher in treated groups which might be due to use of phytoingredients used i.e. certain phytoingredients namely amla, lemon (gulnemu), mint, carrot and pomegranate have contained good amount minerals (Fe in amla is 1.2g; Ca in lemon is 17.1mg along with presence of Fe, Mg, P, K, Na, Zn, Cu, Mn, Se; Mint contains small amount of K, Mg, Ca, P, Fe; Ca content in carrot is 42.2mg, P is 44.8mg, K is 410mg, Na is 88.3mg followed by small amounts of Fe, Zn, Cu, Mn, Se; Pomegrante contains a good amount of Cu, K, Mn, P, lower levels of Mg, Fe, Ca, Zn, Se) and this might be the reason of higher ash content in treated groups. In vacuum packaging, the changes in ash content in the dry products during storage showed minor changes than in aerobic packaging. This study may be supported by the findings of Akhter *et al*., 2009 [2] who also observed decreasing trend in ash content during storage. Similar studies were also observed by Faleye and Fagbohun, 2012 [6].

The results pertaining to water activity of dry meat balls are presented in Table: 5. The mean values of a_w of all the treated and control groups increased significantly during the storage period in both the packaging and drying methods. There is significant difference (p<0.01) between control and treated groups in aerobic packaging. However, no significant differences between the control and treated groups in vacuum packaging and during the storage period were observed. The treatment groups showed high water activity than control groups might be due to higher moisture content. The increase in a_w might be due to increase in moisture content during storage of meat since moisture content is used to determine a_w and vice versa. The higher a_w in treatment groups also might be due to higher moisture content than control groups. The results of water activity of the dried products showed no effect of drying methods on water activity. Due to addition of phytoingredients significantly affected the water activity of the products. Vacuum packaging method resulted in lower water activity of the products.

The results pertaining to TBARS value of dry pork balls are presented in Table: 6. The mean TBARS value in all the samples indicated an increasing trend during the storage period in both the drying methods. There were significant differences between the control and treated groups in aerobic packaging. But in vacuum packaging no significant differences were found.

The increasing trend of TBARS values might be due to lipolysis occurred in the samples during the increased storage period. The values were higher in control samples than the treated groups which might be due to the use of phytoingredients in the treated groups which are rich source of antioxidants. It indicates that the antioxidants might have counteracted lipolysis in the treated groups. In aerobic packaging the products come in contact with moisture along with air and as a result oxidation occurs during storage. This disadvantage can be suppressed by the exclusion of oxygen or by the addition of antioxidants. During vacuum packaging due to exclusion of air or oxygen, rancidity could be prevented. Due to use of phytoingredients containing antioxidants is valuable in intercepting free radical in order to decrease rancidification. Due to presence of some of the spices and condiments such as pepper, clove, garlic etc. containing antimicrobial activity can prevent the products from spoilage. Similar findings were reported by Kim *et al*. (2014) [11] who recorded increase in TBARS values during storage period of dry cured pork and vacuum packaging was not sufficient enough to prevent oxidative changes. Rohlik *et al*. (2013) [18] reported that due to addition of natural antioxidants the TBARS value reduced.

Sensory Evaluation of Rehydrated Meat Balls

The sensory scores of rehydrated Products (Pork balls) are presented in Table 7.

The sensory evaluation studies reveal that the overall acceptability was higher in solar dried treatment groups followed by mechanically dried treatment groups. The treatment groups were more preferred by the consumers than the control groups in both the drying methods. No significant differences were among the drying methods were found. Similar studies were found by Ryoba *et al*. (2013) [19] who found that cured solar dried products were more acceptable.

Table 1: Effects of drying and packaging methods proximate composition of meat balls treated with phytoingredients during storage (mean±se)
Moisture (%)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	10.15 ±0.11^{A}	10.15 ±0.11	10.66 ±0.08^{A}	10.66 ±0.08	10.10±0.05^{A}	10.10±0.05	10.30±0.04^{A}	10.30±0.04
30	11.01 ±0.22^{B}	10.17 ±0.11	11.03 ±0.16^{B}	10.70 ±0.08	11.17±0.12^{B}	10.14 ±0.06	11.67±0.07^{B}	10.34 ±0.03
60	11.63 ±0.15^{C}	10.21 ±0.10	11.67 ±0.15^{C}	10.74 ±0.08	11.82±0.15^{C}	10.19 ±0.05	12.14±0.14^{C}	10.39 ±0.03
90	12.30 ±0.06^{D}	10.26 ±0.10	12.23 ±0.09^{D}	10.79 ±0.08	12.27±0.12^{D}	10.23 ±0.04	12.65±0.06^{D}	10.44 ± 0.03
120	12.71 ±0.06^{E}	10.30 ±0.09	12.65 ±0.10^{E}	10.83 ±0.08	12.75±0.06^{E}	10.27 ±0.04	12.94±0.07^{E}	10.47 ±0.03
150	13.08 ±0.04^{F}	10.35 ±0.09	12.99 ±0.08^{F}	10.87 ±0.08	13.05±0.04^{F}	10.32 ±0.05	13.31±0.09^{F}	10.52 ±0.02
180	13.47 ±0.03^{G}	10.39 ±0.09	13.40 ±0.06^{G}	10.91 ±0.08	13.54±0.08^{G}	10.35 ±0.05	13.59±0.04^{G}	10.56 ±0.03

Mean having different superscript in the column (capital letter) differ significantly (P<0.01).
SE=Standard Error, n=5

Table 2: Effects of drying and packaging methods proximate composition of meat balls treated with phytoingredients during storage (mean±se) Crude Protein (%)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	$_{a}54.31 \pm 0.10^{A}$	54.31 ±0.10	$_{b}53.08 \pm 0.24^{A}$	53.08 ±0.24	$_{a}54.76 \pm 0.42^{A}$	54.76±0.42	$_{b}53.14 \pm 0.21^{A}$	53.14±0.21
30	$_{a}53.39 \pm 0.13^{B}$	54.28 ±0.10	$_{b}52.27 \pm 0.29^{B}$	53.05 ±0.23	$_{a}53.63 \pm 0.26^{AB}$	54.52 ±0.26	$_{b}52.92 \pm 0.25^{B}$	53.10 ±0.20
60	$_{a}52.66 \pm 0.10^{C}$	54.22 ±0.10	$_{b}51.56 \pm 0.21^{C}$	53.00 ±0.23	$_{a}52.94 \pm 0.27^{BC}$	54.46 ±0.27	$_{b}52.40 \pm 0.20^{BC}$	53.06 ±0.20
90	$_{a}51.96 \pm 0.13^{D}$	54.16 ±0.11	$_{b}50.93 \pm 0.22C^{D}$	52.94 ±0.22	$_{a}51.25 \pm 0.36^{CD}$	54.41±0.27	$_{b}51.83 \pm 0.19^{CD}$	53.00 ±0.21
120	$_{a50}.42 \pm 0.18^{DE}$	54.11 ±0.11	$_{b}50.60 \pm 0.15^{D}$	52.87 ±0.32	$_{a}50.96 \pm 0.41^{CD}$	54.36 ±0.28	$_{b}51.23 \pm 0.21^{DE}$	52.94 ±0.20
150	$_{a}49.90 \pm 0.22^{E}$	53.87 ±0.24	$_{b}49.89 \pm 0.23^{E}$	52.84 ±0.22	$_{a}50.35 \pm 0.43^{D}$	54.30 ±0.27	$_{b}50.80 \pm 0.26^{E}$	52.86 ±0.21
180	$_{a}48.58 \pm 0.36^{F}$	53.77 ±0.11	$_{b}48.58 \pm 0.24^{F}$	52.79 ±0.22	$_{a}48.01 \pm 0.55^{E}$	54.25 ±0.27	$_{b}48.67 \pm 0.36^{F}$	52.78 ±0.11

Mean having different superscript in the column (capital letter) differ significantly ($P<0.01$).
Mean having different subscript in the row (small letter, aerobic packaging) differ significantly
SE=Standard Error, n=5

Table 3: Effects of drying and packaging methods proximate composition of meat balls treated with phytoingredients during storage (mean±se) Ether extract (%)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	$a25.50 \pm 0.05^{A}$	25.50 ±0.05	$_{b}24.47 \pm 0.22^{A}$	24.47 ±0.22	$a25.28 \pm 0.09^{A}$	25.28 ±0.09	$_{b}24.56 \pm 0.21^{A}$	24.56 ±0.21
30	$a24.96 \pm 0.05^{B}$	25.46 ±0.05	$_{b}24.02 \pm 0.19^{AB}$	24.45 ±0.21	$a24.73 \pm 0.13^{B}$	25.26 ±0.09	$_{b}23.99 \pm 0.19^{B}$	24.54 ±0.22
60	$a24.51 \pm 0.05^{BC}$	25.42 ±0.04	$_{b}23.70 \pm 0.18^{B}$	24.42 ±0.21	$a24.27 \pm 0.13^{BC}$	25.22 ±0.09	$_{b}23.52 \pm 0.16B^{C}$	24.51 ±0.22
90	$a24.11 \pm 0.06^{CD}$	25.37 ±0.04	$_{b}23.40 \pm 0.19^{BC}$	24.38 ±0.21	$a23.92 \pm 0.13^{C}$	25.17 ±0.09	$_{b}23.00 \pm 0.12^{CD}$	24.47 ±0.22
120	$a23.65 \pm 0.09^{DE}$	25.32 ±0.04	$_{b}22.93 \pm 0.18^{C}$	24.34 ±0.21	$a23.36 \pm 0.04^{D}$	25.12 ±0.09	$_{b}22.87 \pm 0.16^{D}$	24.43 ±0.22
150	$a23.29 \pm 0.17^{E}$	25.28 ±0.04	$_{b}22.83 \pm 0.19^{C}$	24.30 ±0.21	$a23.12 \pm 0.19^{D}$	25.11 ±0.39	$_{b}22.63 \pm 0.16^{D}$	24.40 ±0.21
180	$a22.72 \pm 0.41^{F}$	25.26 ±0.07	$_{b}22.59 \pm 0.24^{D}$	24.27 ±0.21	$a22.65 \pm 0.27^{E}$	25.05 ±0.10	$_{b}22.42 \pm 0.21^{E}$	24.38 ±0.24

Mean having different superscript in the column (capital letter) differ significantly ($P<0.01$).
Mean having different subscript in the row (small letter, aerobic packaging) differ significantly
SE=Standard Error, n=5

Table 4: Effects of drying and packaging methods proximate composition of meat balls treated with phytoingredients during storage (mean±se) Total Ash (%)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	$_{a}5.74 \pm 0.12^{A}$	5.74 ±0.12	$_{b}5.82 \pm 0.12^{A}$	5.82 ±0.12	$_{c}5.53 \pm 0.04^{A}$	5.53 ± 0.04	$_{d}5.94 \pm 0.07^{A}$	5.94 ±0.07
30	$_{a}5.82 \pm 0.12^{A}$	5.75 ±0.12	$_{b}5.87 \pm 0.11^{A}$	5.84 ±0.11	$_{c}5.58 \pm 0.04^{AB}$	5.55 ±0.03	$_{d}5.97 \pm 0.07^{A}$	5.96 ±0.07
60	$_{a}5.91 \pm 0.10^{AB}$	5.80 ±0.11	$_{b}5.97 \pm 0.09^{AB}$	5.86 ±0.11	$_{c}5.70 \pm 0.03^{ABC}$	5.58 ±0.03	$_{d}6.05 \pm 0.08^{AB}$	5.97 ± 0.08
90	$_{a}6.00 \pm 0.10^{AB}$	5.82 ±0.11	$_{b}6.07 \pm 0.08^{ABC}$	5.88 ±0.10	$_{c}5.84 \pm 0.08^{BCD}$	5.61 ±0.02	$_{d}6.13 \pm 0.09A^{BC}$	5.99 ±0.08
120	$_{a}6.22 \pm 0.10^{B}$	5.83 ±0.11	$_{b}6.22 \pm 0.08^{BC}$	5.90 ±0.10	$_{c}5.91 \pm 0.11^{CDE}$	5.63 ±0.02	$_{d}6.16 \pm 0.12^{ABC}$	6.00 ±0.08
150	$_{a}6.21 \pm 0.13^{B}$	5.85 ±0.11	$_{b}6.26 \pm 0.10^{BC}$	5.92 ±0.09	$_{c}6.07 \pm 0.12^{DE}$	5.66 ±0.03	$_{d}6.29 \pm 0.11^{BC}$	6.01 ±0.09
180	$_{a}6.29 \pm 0.14^{B}$	5.87 ±0.11	$_{b}6.33 \pm 0.10^{C}$	5.94 ±0.09	$_{c}6.15 \pm 0.14^{E}$	5.67 ±0.03	$_{d}6.39 \pm 0.12^{C}$	6.03 ±0.09

Mean having different superscript in the column (capital letter) differ significantly ($P<0.01$).
Mean having different subscript in the row (small letter=Aerobic packaging) differ significantly ($P<0.01$)
SE=Standard Error, n=5

Table 5: Effect of drying and packaging methods Water activity (a_w) of meat balls treated with phytoingredients during storage (mean±se)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	$^{A}0.60 \pm 0.0024^{b}$	0.60±0.0024	$^{A}0.63 \pm 0.0008^{a}$	0.63±0.0008	$^{A}0.61 \pm 0.0020^{b}$	0.61±0.0020	$^{A}0.62 \pm 0.0022^{a}$	0.62±0.0022
15	$^{B}0.62 \pm 0.0027^{b}$	0.63±0.0008	$_{A}{}^{B}0.63 \pm 0.0004^{a}$	0.60±0.0021	$^{B}0.62 \pm 0.0028^{b}$	0.62±0.0022^{a}	$^{AB}0.63 \pm 0.0013^{a}$	0.61±0.0020
30	$^{C}0.63 \pm 0.0018^{b}$	0.63±0.0010	$^{B}0.64 \pm 0.0024^{a}$	0.60±0.0021	$^{C}0.63 \pm 0.0024^{b}$	0.62±0.0022^{a}	$^{BC}0.64 \pm 0.0020^{a}$	0.61±0.0020
45	$^{D}0.64 \pm 0.0020^{b}$	0.63±0.0010	$^{C}0.65 \pm 0.0023^{a}$	0.61±0.0021	$^{D}0.64 \pm 0.0033^{b}$	0.62±0.0022^{a}	$^{CD}0.65 \pm 0.0030^{a}$	0.61±0.0020
60	$^{E}0.65 \pm 0.0016^{b}$	0.63± 0.0010	$^{D}0.67 \pm 0.0033^{a}$	0.61±0.0021	$^{E}0.65 \pm 0.0019^{b}$	0.63±0.0022^{a}	$^{DE}0.67 \pm 0.0042^{a}$	0.61±0.0020
75	$^{EF}0.66 \pm 0.0016^{b}$	0.63±0.0010	$^{E}0.68 \pm 0.0047^{a}$	0.61±0.0020	$^{F}0.66 \pm 0.0015^{b}$	0.63±0.0023^{a}	$^{E}0.68 \pm 0.0047^{a}$	0.61±0.0020
90	$^{F}0.67 \pm 0.0027^{b}$	0.63±0.0010	$^{F}0.69 \pm 0.0035^{a}$	0.61±0.0020	$^{G}0.68 \pm 0.0041^{b}$	0.63±0.0023^{a}	$^{F}0.69 \pm 0.0077^{a}$	0.61±0.0020

105	$^{G}0.68\pm0.0049^{b}$	0.63±0.0009	$^{G}0.70\pm0.0049^{a}$	0.61±0.0020	$^{H}0.69\pm0.0036^{b}$	0.63±0.0023^{a}	$^{G}0.71\pm0.0052^{a}$	0.61±0.0021
120	$^{H}0.69\pm0.0055^{b}$	0.63±0.0010	$^{G}0.71\pm0.0041^{a}$	0.61±0.0020	$^{I}0.70\pm0.0062^{b}$	0.63±0.0023^{a}	$^{G}0.72\pm0.0058^{a}$	0.61±0.0021
135	$^{I}0.70\pm0.0055^{b}$	0.64±0.0009	$^{H}0.72\pm0.0047^{a}$	0.61±0.0020	$^{J}0.72\pm0.0060^{b}$	0.63±0.0023^{a}	$^{H}0.73\pm0.0072^{a}$	0.61±0.0021
150	$^{J}0.72\pm0.0028^{b}$	0.64±0.0009	$^{H}0.73\pm0.0035^{a}$	0.61±0.0020	$^{K}0.73\pm0.0046^{b}$	0.63±0.0023^{a}	$^{HI}0.74\pm0.0080^{a}$	0.61±0.0021
165	$^{K}0.73\pm0.0025^{b}$	0.64±0.0008	$^{I}0.75\pm0.0034^{a}$	0.61±0.0020	$^{L}0.75\pm0.0036^{b}$	0.63±0.0023^{a}	$^{IJ}0.75\pm0.0060^{a}$	0.61±0.0021
180	$^{L}0.75\pm0.0026^{b}$	0.64±0.0008	$^{J}0.76\pm0.0037^{a}$	0.61±0.0021	$^{L}0.76\pm0.0036^{b}$	0.63±0.0023^{a}	$^{J}0.77\pm0.0033^{a}$	0.61±0.0021

Mean having different superscript in the column (capital letter) differ significantly (P<0.01).
Mean having different superscript in the row (small letter=Aerobic packaging) differ significantly (P<0.01)
SE=Standard Error, n=5

Table 6: Effect of drying and packaging methods TBARS value (malonaldehyde mg/kg) of meat balls treated with phytoingredients during storage (mean±se)

Storage period (days)	Drying methods							
	Solar Dried				Mechanically Dried			
	Control (A)		Treatment (B)		Control (C)		Treatment (D)	
	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging	Aerobic Packaging	Vacuum Packaging
0	$^{A}0.150\pm0.007^{a}$	0.150±0.007	$^{A}0.108\pm0.004^{b}$	0.108±0.004	$^{A}0.162\pm0.003^{a}$	0.162±0.003	$^{A}0.108\pm0.003^{b}$	0.108±0.003
15	$^{B}0.202\pm0.008^{a}$	0.166±0.008^{a}	$^{B}0.130\pm0.006^{b}$	0.148±0.006^{b}	$^{B}0.206\pm0.008^{a}$	0.164± 0.002^{a}	$^{B}0.128\pm0.003^{b}$	0.116±0.002^{c}
30	$^{C}0.262\pm0.008^{a}$	0.170±0.008^{a}	$^{C}0.154\pm0.005^{b}$	0.158±0.006^{a}	$^{C}0.248\pm0.009^{a}$	0.182±0.003^{a}	$^{C}0.150\pm0.003^{b}$	0.126±0.002^{b}
45	$^{D}0.326\pm0.009^{a}$	0.186±0.008^{a}	$^{D}0.180\pm0.006^{c}$	0.162±0.007^{a}	$^{D}0.292\pm0.013^{b}$	0.198±0.002^{a}	$^{D}0.172\pm0.003^{c}$	0.136±0.002^{b}
60	$^{E}0.384\pm0.010^{a}$	0.200±0.007^{a}	$^{E}0.210\pm0.006^{b}$	0.178±0.008^{a}	$^{E}0.354\pm0.016^{a}$	0.208±0.004^{a}	$^{E}0.200\pm0.006^{b}$	0.146±0.002^{b}
75	$^{F}0.448\pm0.008^{a}$	0.216±0.008^{a}	$^{F}0.238\pm0.004^{c}$	0.180±0.008^{a}	$^{F}0.404\pm0.016^{b}$	0.226±0.005^{a}	$^{F}0.222\pm0.003^{c}$	0.150±0.003^{b}
90	$^{G}0.506\pm0.006^{a}$	0.222±0.006^{a}	$^{G}0.268\pm0.005^{c}$	0.182±0.008^{a}	$^{G}0.452\pm0.015^{b}$	0.242±0.004^{a}	$^{G}0.252\pm0.007^{c}$	0.162±0.002^{b}
105	$^{H}0.564\pm0.007^{a}$	0.234±0.007^{a}	$^{H}0.298\pm0.005^{c}$	0.190±0.007^{a}	$^{H}0.498\pm0.014^{b}$	0.250±0.005a	$^{H}0.280\pm0.010^{c}$	0.166±0.004^{b}
120	$^{I}0.614\pm0.008^{a}$	0.246±0.015^{a}	$^{I}0.320\pm0.005^{c}$	0.200±0.007^{a}	$^{I}0.552\pm0.014^{b}$	0.266±0.006^{a}	$^{I}0.310\pm0.010^{c}$	0.174±0.005^{b}
135	$^{J}0.672\pm0.009^{a}$	0.258±0.005^{a}	$^{J}0.346\pm0.008^{c}$	0.202±0.008^{a}	$^{J}0.602\pm0.011^{b}$	0.282±0.005^{a}	$^{J}0.334\pm0.010^{c}$	0.184±0.006^{b}
150	$^{K}0.718\pm0.009^{a}$	0.272±0.003^{a}	$^{K}0.366\pm0.011^{c}$	0.216±0.007^{a}	$^{K}0.648\pm0.015^{b}$	0.300±0.004^{a}	$^{K}0.358\pm0.009^{c}$	0.194±0.005^{b}
165	$^{L}0.764\pm0.008^{a}$	0.288±0.003^{a}	$^{L}0.394\pm0.009^{c}$	0.218±0.005^{a}	$^{L}0.688\pm0.012^{b}$	0.308±0.003^{a}	$^{L}0.382\pm0.010^{c}$	0.206±0.005^{b}
180	$^{M}0.780\pm0.007^{a}$	0.302±0.003^{a}	$^{M}0.420\pm0.006^{c}$	0.220±0.006^{b}	$^{M}0.720\pm0.011^{b}$	0.310±0.004^{a}	$^{M}0.408\pm0.008^{c}$	0.218±0.005^{c}

Means having same superscript in the row (small letter, aerobic packaging) do not differ significantly (P<0.01)
Means having same superscript in the column (capital letter) do not differ significantly (P<0.01)
SE=Standard Error, n=5

Table 7: Sensory Evaluations of Rehydrated Products (Pork Balls) (A= Solar Dried Control, B= Solar Dried treatment, C= Mechanically dried Control, D= Mechanically Dried Treatment)

Treatment Group	Mean±SE				
	Appearence	Flavour	Juiciness	Tenderness	Overall acceptability
A	5.836 ± 0.171^{A}	5.968 ± 0.190^{A}	5.150 ± 0.049^{A}	5.212 ± 0.043^{A}	5.542 ± 0.190^{AB}
B	6.300 ± 0.233^{A}	6.200 ± 0.201^{A}	5.440 ± 0.100^{B}	5.320 ± 0.089^{A}	5.815 ± 0.109^{C}
C	5.794 ± 0.207^{A}	5.780 ± 0.200^{A}	5.128 ± 0.067^{A}	5.044 ± 0.091^{A}	5.437 ± 0.246^{D}
D	6.136 ± 0.257^{A}	6.144 ± 0.205^{A}	5.222 ± 0.086^{AB}	5.284 ± 0.108^{A}	5.670 ± 0.127^{AC}

Means with the same superscript column wise (capital letter, meat balls) differ significantly (P<0.01)
SE= Standard Error, n=5

Conclusion

Dry pork products (meat balls) with stable physico-chemical graphics can be produced by using a solar dryer under hygienic conditions. Antioxidant rich phytoingredients had shown added advantage in producing a dry pork product. Vacuum packaging method resulted in better quality products than aerobic packaging. Solar dried products had similar qualities like mechanically dried products, therefore, it can be recommended over oven dried products with in energy deficient areas where surplus meat can be preserved hygienically.

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Reference

1. Ajiboye EA, Alhassan S, Adedayo RM, Kolawole MO, Oladosu OT. Physicochemical properties and microorganisms isolated from dried meat obtained in Oja- Oba market in Ilorin, Nigeria. Advances in Applied Science Research. 2011; 2(4):391-400.
2. Akhter S, Rahman M, Hossain MM, Hashem MA. Effects of drying as a preservation technique on nutrient contents of beef. Journal of Bangladesh Agril. Univrsity. 2009; 7(1):63-68.
3. AOAC. Official Methods of Analysis. Association of Official Analytical Chemist, 11th Edn. USDA, Washington DC, 1970.
4. Attmann HJ, Grunov W, Mohr U, Richterreichhelm MB, Wester PW. Effects of BHA and related phenols on the forestomach of rats. Food Chemistry and Toxicology. 1986; 24:1183-1188.
5. Decker EA, Mei L. Antioxidants mechanisms and applications in muscle foods, In: Proceedings of the Reciprocal Meat Conference, 1986, 64-72.
6. Faleye OS, Fagbohun ED. Effects of storage on the proximate, mineral composition and mycoflora of “Tinco” dried meat sold in oshodi market, Lagos state,

Nigeria. Global Journal of Bio-Science and Biotechnology. 2012; 1:54-58.
7. Forrest JC, Aberle ED, Hedrick HB, Judge MD, Merkel RA. Principles of Meat Science. Freeman and Company USA, 1975, 257-288.
8. Gonzalez MT, Hafley BS, Boleman RM, Miller RK, Rhee KS, Keeton JT *et al*. Antioxidant properties of plum concentrates and powder in precooked roast beef to reduce lipid oxidation. Meat Science. 2008; 80:997-1004.
9. Hotchkiss HJ, NJ Potter. Heat preservation and processing. Food science, Edn 5, New York, 1995, 261-265.
10. Juntachote T, Berghofer E, Siebenhandl S, Bauer F. The oxidative properties of holy basil and Galangal in cooked ground pork. Meat Science. 2006; 72:446-456.
11. Kim S, Jin SK, Yang MR, Ahn DU, Park JH, Kang SN *et al*. Effect of packaging method and storage time on physicochemical characteristics of dry-cured pork neck products at 10°C. Asian Australian Journal of Animal Science. 2014; 27:1623-1629.
12. Naveena BM, Sen AR, Vaithiyanathan S, Babji Y, Kondaiah N. Comparative efficacy of pomegranate juice, pomegranate rind powder extract and BHT as antioxidants in cooked chicken patties. Meat Science. 2008; 80**:**304-308.
13. Ockerman HW. Quality control of post mortem muscle tissue. Department of Animal Sciences. The Ohio State University and the Ohio Agricultural Research and Development Centre, Columbus and Wooster, Ohio, USA, 1985. 51.0-51.2 and 70.1-80.1.
14. Pearson D. Assessment of meat freshness in quality control employing chemical techniques, a review. Journal of Science of Food and Agriculture. 1968; 19:357.
15. Powell CJ, Connelly JC, Jones SM, Grasso P, Bridges J. W. Hepatic responses to the administration of high dose of BHT to the rat; their relevance to hepatocarcinogenicity. Food Chemistry and Toxicology. 1986; 24:1131-1143.
16. Rababah TM, Hettiarachchy NS, Horax R. Total phenolics and antioxidant activities of fenugreek, green tea, black tea, grape seed, ginger, rosemary, gotu kola and ginkgo extracts, vitamin E and turtbutylhydroquinone. Journal of Agriculture and Food Chemistry. 2004; 52:5183-5186.
17. Ranganna S. Hand book of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1986, 976-979.
18. Rohlik BA, Pipek P, Panek J. The effect of natural antioxidants on the colour and lipid stability of paprika salami. Czech Journal of Food Science. 2013; 31:307-312.
19. Ryoba RN, Muhikambele VR, Mtenga lA, Mgheni DM. Comparative assessment of drying methods, curing agents and meat cut size on the quality and preservation of meat under rural setting perspectives. Livestock Research and Rural Development. 2013; 25:13-20.
20. Witte VC, Krause GF, Barley ME. A new extraction method for determining 2-thiobarbituric acid values for pork and beef during storage. Journal of Food Science. 1970; 35:582.