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UTILIZATION OF VACUUM-DRYING FOR REDUCTION OF PEPPERONI DRYING TIME.

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INTRODUCTION. Drying is the final process in the manufacture of pepperoni and permit further development of flavor and textural traits (Genigeorgis, 1978). Application of new or existing technologies to shorten drying time could be of great economic importance for the production of pepperoni. A few applications have been reported to shorten the drying time by the use of freeze-dried meat (Lu and Townsend, 1973) and Pale, Soft, Exudative (PSE) pork (Townsend et al., 1980; Honkavaara, 1988). Therefore, the objectives for this study were: to assess the effectiveness of vacuum to accelerate the drying process; to determine the temperature (°C) and vacuum combination that are most effective for reducing drying time as compared to a conventional process; and to characterize the chemical composition and physical characteristics of pepperoni dried under vacuum as compared to conventional process.

MATERIALS AND METHODS. Commercially processed pepperoni sticks were fermented and shipped to the Meat Science laboratory at Texas A&M University. Twelve pepperoni sticks (5 cm, diameter) were placed into laboratory model vacuum chambers held at 17°, 19° or 22°C, respectively, and vacuum adjusted to 100 kPa for a total drying period of 15 days. Pepperoni samples were taken at three day intervals to evaluate their physico-chemical properties to an endpoint moisture:protein (M:P) ratio of 1.6:1. Pepperoni sticks (controls) from the same manufacturing lot were dried under commercial conditions and sampled every three days of drying to compare with vacuum dried samples.
Percentage weight loss (%) and proximate analysis were determined according to AOAC (1990). pH-values were determined using pH-meter (Model No. 610, Orion Research, Inc.). Water activity values (Aw) were measured with a Rotronic Hygroskop DT system (Model, D2100) equipped with a sensor (Model, DMS 100 H) covering the range of 0.80 to 0.95 Aw. After slicing to 5 mm sections, diameters (cm) were made using calipers at three different sites on each slice. Allo-Kramer shear measurements were performed using an Instron Universal Testing Machine (Model, 1011) equipped with a multi-bladed Allo-Kramer shear attachment. Ten shear measurements were made on individual pepperoni slices using a 500 kg load cell with a 30 sec downstroke over a shear load range of 100 kg. Color values were determined with a Hunter Colorimeter and Color Difference Meter fitted with an M head. The instrument was standardized with a white plate (L = 91.74, a = -0.97, b = 1.46) and the results were expressed as Hunter-L (whiteness), a (redness), and b (yellowness) values.
Data were analyzed by analysis of variance using the general linear model (GLM) procedure of SAS statistics package (SAS, 1985). When treatment effects were significant, mean separation was accomplished using the Student-Newman-Kuels procedure.

RESULTS AND DISCUSSION. Pepperoni sticks dried at 17°, 19° or 22°C under vacuum were not different ($P>0.05$) for moisture, fat or protein contents (%), but vacuum drying over 12 day produced pepperoni that was comparable to the 18 day commercial drying process. As vacuum dried samples reached a M:P ratio of 1.6:1 (9 to 12 days), the moisture content (%) ranged from 29 to 30 % (Acton and Dick, 1976). The drying rate was faster for samples under vacuum than those not under vacuum. Fat and protein contents (%) increased during drying due to a proportionate decrease in moisture (%). After the 3rd day of vacuum drying, total fat (%) of the 19°C treatment tended to be higher than control (Table 1).
The USDA-FSIS mandated M:P ratio of 1.6:1 was achieved between 9 to 12 days of vacuum drying, whereas, a M:P ratio of 1.7:1 was reached after 15 days of conventional drying (Table 2). Therefore, approximately 30 % of the drying time can be reduced with the use of vacuum drying. During pepperoni drying, the pH range was 4.53-4.66 regardless of drying treatment and this pH result was similar to that of Townsend et al.(1980). Water activity (Aw) of all treatments decreased proportionally during drying, and there were no differences ($P>0.05$) among temperature treatments until day 15. When the vacuum dried pepperoni reached a M:P ratio 1.6:1 on day 12, Aw was 0.88.
Weight loss (%) under vacuum drying was greater ($P<0.05$) than that of the control after 6 days of drying and remained higher through day 15. Weight loss of vacuum dried samples on day 12 ranged from 21 to 23 %. During drying, Kramer shear force values increased ($P<0.05$) in all treatments, while the diameters (cm) decreased proportionally with the loss of moisture (%). Shear force values in all vacuum dried samples were higher ($P<0.05$) than those in the control after 6 days and varied 0.36 to 0.38 kg/g-cm^2 when pepperoni samples reached a M:P ratio of 1.6:1 (Table 3).
Hunter L (whiteness) and b (yellowness) values decreased ($P<0.05$) with drying time in all treatments and no differences ($P>0.05$) were noted in Hunter a (redness) values except for the initial 22°C treatment and at day 15. Vacuum dried pepperoni color at each sampling day did not differ ($P>0.05$) in Hunter L values from the control, but tended to have less redness and yellowness.

CONCLUSIONS. Pepperoni samples dried under vacuum achieved a M:P ratio of 1.6:1 after 9 to 12 days of drying regardless temperature. This represents approximately a 30% reduction in drying time without noticable quality defects. Thus, vacuum drying appears to be a feasible alternative for reducing the drying time of pepperoni under laboratory conditions. Futher testing with a pilot plant or large scale vacuum chamber will be required to determine scale-up effects and their influence on product quality and drying efficiency.

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Table 1. Chemical composition of pepperoni dried at three different temperatures under vacuum (100 kPa) over 15 day.

Days	Moisture (%)				Fat (%)				Protein (%)			
	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C
0	45.3^{ax}	44.8^{ax}	44.4^{ax}	45.2^{ax}	35.0^{ex}	34.8^{ex}	35.9^{ex}	35.3^{ex}	14.2^{dx}	14.0^{ex}	13.9^{cx}	13.8^{ex}
3	40.6^{bx}	40.5^{bx}	40.0^{bx}	39.4^{bx}	36.4^{ey}	37.0^{dxy}	38.4^{dx}	37.7^{dxy}	15.8^{cx}	15.0^{dx}	14.7^{cx}	15.5^{dx}
6	38.3^{cx}	35.8^{cy}	36.1^{cy}	35.0^{cy}	38.6^{dy}	40.3^{cxy}	41.4^{cx}	40.9^{cxy}	17.0^{bcx}	16.4^{cx}	16.9^{bx}	17.0^{cx}
9	35.1^{dx}	31.8^{dy}	32.0^{dy}	33.0^{dy}	41.2^{cy}	43.4^{bx}	43.1^{bx}	42.5^{bxy}	17.4^{bx}	17.6^{bcx}	17.8^{abx}	17.6^{bcx}
12	32.4^{ex}	29.4^{ey}	29.5^{ey}	28.9^{ey}	42.4^{bcy}	44.5^{bx}	44.8^{ax}	44.7^{ax}	18.0^{abx}	18.3^{bx}	18.6^{ax}	18.7^{abx}
15	30.2^{efx}	26.6^{fy}	27.4^{fy}	26.3^{fy}	44.2^{aby}	46.3^{ax}	46.1^{ax}	45.4^{axy}	18.6^{aby}	20.0^{ax}	18.9^{axy}	19.5^{ax}
18	28.0^{f}	.	.	.	45.4^{a}	.	.	.	19.3^{a}	.	.	.

a,b,c,d,e,f Means among days within drying temperature treatments having the same superscript are not significantly different (P>0.05); x,y,z Means among drying temperature treatments within days having the same superscript are not significantly different (P>0.05).

Table 2. M:P ratio, pH and water activity of pepperoni dried at three different temperatures under vacuum (100 kPa) over 15 days.

Days	M:P ratio				pH				Aw			
	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C
0	3.24^{ax}	3.21^{ax}	3.14^{ax}	3.27^{ax}	4.54^{ax}	4.65^{ax}	4.55^{ax}	4.55^{ax}	0.94^{ax}	0.94^{ax}	0.93^{ax}	0.94^{ax}
3	2.58^{bx}	2.69^{bx}	2.72^{bx}	2.55^{bx}	4.57^{ax}	4.65^{ax}	4.61^{ax}	4.54^{ax}	0.92^{abx}	0.93^{abx}	0.92^{abx}	0.92^{abx}
6	2.26^{cx}	2.06^{cx}	2.13^{cx}	2.07^{cx}	4.60^{ax}	4.59^{ax}	4.59^{ax}	4.53^{ax}	0.91^{bcx}	0.91^{bx}	0.91^{bx}	0.91^{bcx}
9	2.01^{cdx}	1.81^{dxy}	1.80^{dy}	1.88^{cxy}	4.63^{ax}	4.60^{ax}	4.59^{ax}	4.57^{ax}	0.90^{cdx}	0.89^{cx}	0.90^{bx}	0.90^{cdx}
12	1.81^{dex}	1.60^{dxy}	1.59^{dey}	1.56^{dy}	4.66^{ax}	4.64^{ax}	4.58^{ax}	4.61^{ax}	0.89^{dex}	0.88^{cx}	0.88^{cx}	0.88^{dx}
15	1.70^{ex}	1.33^{ey}	1.45^{ey}	1.35^{dy}	4.64^{ax}	4.64^{ax}	4.56^{ax}	4.58^{ax}	0.88^{ex}	0.85^{dy}	0.86^{dy}	0.86^{ey}
18	1.45^{f}	.	.	.	4.63^{a}	.	.	.	0.87^{e}	.	.	.

Table 3. Weight loss, Diameter and Kramer shear force values of pepperoni dried at three different temperatures under vacuum (100 kPa) over 15 days.

Days	Weight loss (%)				Diameter (cm)				Shear Force (kg/g-cm²)			
	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C	CTL	17°C	19°C	22°C
0	.	.	.	.	5.00^{ax}	5.00^{ax}	5.00^{ax}	5.00^{ax}	0.15^{cx}	0.17^{ex}	0.19^{ex}	0.18^{ex}
3	6.05^{fx}	6.87^{ex}	7.76^{ex}	6.95^{ex}	4.92^{ax}	4.85^{bxy}	4.83^{by}	4.88^{bxy}	0.17^{bcx}	0.22^{dex}	0.23^{dex}	0.21^{dex}
6	9.00^{ey}	13.76^{dx}	12.86^{dx}	12.32^{dx}	4.79^{bx}	4.72^{cxy}	4.67^{cy}	4.75^{cxy}	0.20^{by}	0.25^{cdx}	0.29^{cdx}	0.26^{cdx}
9	13.32^{dz}	19.45^{cx}	17.02^{cy}	16.42^{cy}	4.74^{bx}	4.58^{dy}	4.63^{cy}	4.63^{dy}	0.26^{aby}	0.31^{cxy}	0.31^{cx}	0.29^{bcxy}
12	15.88^{cz}	23.22^{bx}	20.78^{by}	20.49^{by}	4.62^{cx}	4.48^{ey}	4.53^{dy}	4.48^{ey}	0.29^{ay}	0.38^{bx}	0.38^{bx}	0.36^{abx}
15	19.05^{bz}	26.17^{ax}	23.81^{ay}	23.56^{ay}	4.59^{cdx}	4.41^{ey}	4.43^{ey}	4.40^{ey}	0.32^{az}	0.46^{ax}	0.49^{ax}	0.42^{ay}
18	21.83^{a}	.	.	.	4.52^{d}	.	.	.	0.34^{a}	.	.	.

a,b,c,d,e,f Means among days within drying temperature treatments having the same superscript are not significantly different (P>0.05); x,y,z Means among drying temperature treatments within days having the same superscript are not significantly different (P>0.05).