EFFECT OF COLD STORAGE ON PHYSICAL AND SENSORY QUALITY ATTRIBUTES OF BROILER CHICKEN MEAT

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Abstract
This study investigated physical and sensory quality attributes of broiler chicken meat stored at -20^{0}C. Sixty birds were allotted into 5-treatment in a completely randomized design and each treatment had (n = 12, r = 3). Treatment 1 (T1: fresh un-stored meat) and meat stored for 1, 2, 3 and 4 weeks were used as T2, T3, T4 and T5 respectively. Samples were assessed for physical attributes: cooking loss, water holding capacity (WHC), thermal shortening and thaw loss. Sensory qualities were assessed using the 9-point hedonic scale. Data were analyzed using ANOVA at $\alpha_{0.05}$. Thaw loss of breast, thigh and drumstick in T2 (breast: 6.21%; thigh: 2.30%; drumstick: 1.90%) were significantly lower than other treatments (T1 exempted). Cooking loss of breast, thigh and drumstick in T1 (breast: 14.59%; thigh: 20.85%; drumstick: 13.32%) were significantly lower compared to other treatments. WHC for breast, thigh and drumstick in T1 (breast: 79.03%; thigh: 80.10%; drumstick: 78.16%) were significantly higher than other treatments but not significantly different from T2 (breast: 76.66%; thigh: 76.46%; drumstick: 77.43). Thermal shortening of breast, thigh and drumstick in T5 (breast: 30.67%; thigh: 34.67%; drumstick: 54.67%) were significantly higher compared to other treatments. Sensory quality of breast, thigh and drumstick in terms of overall acceptability in T1 (breast:7.27; thigh: 7.10; drumstick: 7.26) had significant higher preference compared to other treatments. It was concluded that the physical and sensory attributes of broiler chicken meat had the tendency of being negatively affected by cold storage particularly when stored beyond one week.

Key words: Broiler chicken, cold storage, meat quality attributes, breast meat, thigh meat, drumstick meat

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1. INTRODUCTION

Chicken meat is economically important refrigerated or frozen food which is highly consumed in Europe and African countries (Ogunbawo *et al.*, 2006). The meat has become the most important form of animal protein and its consumption has increased due to the need of consumers for convenient ready-to-eat foods and the desire to live healthily since the meat is considered as white meat.

The challenges of chicken meat as fresh muscle foods are their limited storage life since quality deteriorations of the meat increases with storage period (Pavelkova *et al.*, 2013; Bowker and Zhuang, 2015). Lipid oxidation is one of the main factors limiting the quality, acceptability and physical changes of chicken meat. A rapid deterioration can be observed in improperly stored meat which may result in changes in quality value, unacceptable to consumers and in meat spoilage (Polawska *et al.*, 2011). Meat is usually accepted or purchased based on their appearance, colour and texture but these quality attributes are inadequate in assessing the sensory and physical attributes of consumers' preference for good quality meat. Thus, meat is considered of poor quality not only because of colour (pale) but also due to high drip loss, high cooking loss, low water holding capacity, reduced juiciness and poor emulsifying capacity (Johnston *et al.*, 2005, Estevez, 2011).

Sensory quality attributes such as colour, flavor, juiciness, taste, texture and tenderness are affected by the physical quality attributes (cooking loss, drip loss, water holding capacity, thaw loss and thermal shortening) changes that take place in the meat during storage. Sensory evaluation is the scientific discipline that applies principles of experimental design and statistical analysis to the use of human senses (sight, smell, taste, touch and hearing) for the purpose of evaluating consumers' preference for the tested products and the responses made by them are assessed by hedonic scale rating (Heinz and Hautzinger, 2007).

The physical change in stored meat in form of water holding capacity is the ability of a piece of meat to retain its naturally occurring water during application of any external force such as cutting, grinding or pressing and it is one of the important meat properties in processing meat products because it affects the yield colour, tenderness, juiciness, and texture of raw and cooked meat (Aduku and Olukosi, 2000). The quality of frozen food is closely related to freezing and thawing processes. During thawing process foods are subjected to damage by chemical and physical changes and microbial attack. For assurance of food quality quick thawing at low temperature while avoiding notable rise in temperature and increased dehydration is desirable. The longer the thawing treatment time, the higher will be the microbial growth on product surface (Leygonie *et al.*, 2012).

However, to reduce spoilage of chicken meat during storage; preservation method such as cold storage (freezing) has been in use (Heinz and Hautzinger, 2007). Freezing is one of the preservation methods which helps in maintaining quality of meat and extend its shelf life (Leygonie *et al.*, 2012). Thus, this study focused on evaluating cold storage on physical and sensory quality attributes of broiler chicken with a view to optimizing cold storage on meat quality and consumers' preference.

2. MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Poultry Experimental Unit of the Federal College of Animal Health and Production Technology, Moor Plantation, Ibadan, Nigeria. The broiler chicken meat was stored under the ambient temperature of -20^{0}C in a cold room.

Experimental animal and processing

A total number of sixty (60) birds were purchased from a reputable farm in Ibadan, Oyo state. The birds were deprived of feed and fasted for 8 hours, weighed prior to slaughtering. The slaughtering was done manually using a knife to cut through the jugular in a bleeding cone device; the birds were thoroughly bled in the cone before been removed.

Scalding was carried out in hot water of 55 to 60^{o}C was poured on each carcass to soften the feathers and they were defeathered using a defeathering machine. Carcasses were eviscerated and all organs were removed carefully to avoid contamination. They were washed and cut into primal cuts (breast, thigh and drumstick) and then each primal cuts were weighed.

Preservation of the meat and experimental design

The primal cuts were preserved in a cold room with ambient temperature of -20^{o}C for 7 days (1 week), 14 days (2 weeks), 21 days (3 weeks) and 28 days (4 weeks) respectively. The breast, thigh and drumstick were randomly selected and allotted into four storage treatments and were replicated three times with 6 meat primal cuts (2 breasts, 2 thighs and 2 drumsticks) per replicate using completely randomized design. The treatments are:

T1 - Fresh broiler chicken meat not stored.

T2 - Broiler chicken meat parts (breast, thigh and drumstick) stored at -20^{o}C for 7 days (1 week).

T3 – Broiler chicken meat parts (breast, thigh and drumstick) stored at -20^{o}C for 14 days (2 weeks).

T4 – Broiler chicken meat parts (breast, thigh and drumstick) stored at -20^{o}C for 21 days (3 weeks).

T5 – Broiler chicken meat parts (breast, thigh and drumstick) stored at -20ºC for 28 days (4 weeks).

At the end of each storage days the breast, thigh and drumstick samples were assessed for thaw loss, water holding capacity, cooking loss, thermal shortening and sensory evaluation (colour, flavour, taste, texture and overall acceptability).

Physical meat quality attributes

The physical quality attributes evaluated were the thaw loss, cooking loss, thermal shortening and water holding capacity of the stored meat. Freshly cut breast, thigh and drumstick meat sliced to approximately 2 cm thick, 20g and 6 cm long respectively were used in three replicates each for breast, thigh and drumstick meat in determining the thaw loss, cooking loss, thermal shortening and water holding capacity.

The thaw loss was determined by weighing each of the meat streaks from breast, thigh and drumstick prior to freezing and again after thawing. The method of thawing employed involved immersing the meat samples in water (25 ±1 ºC) container for 15 minutes (Rahman *et al.*, 2014). The thaw loss was not assessed on the fresh meat samples since it was not frozen. Thaw loss was expressed as a percentage of initial weight prior to freezing.

$$\text{Thaw loss (\%)} = \frac{\text{Sample weight before freezing (g)} - \text{Sample weight after thawing (g)}}{\text{Sample weight before freezing (g)}} x\ 100$$

The cooking loss was determined by using freshly cut breast, thigh and drumstick meat sliced to approximately 2 cm thick, 20g and 6 cm long respectively. Three streaks from breast, thigh and drumstick muscle were obtained from the five treatments and were placed in sealed polytene bags immersed in boiling water for 20 minutes to 72ºC doneness of the meat. The meat samples were cooled for 10 minutes at room temperature (25 ±1 ºC) to determine the cooking loss for the breast, thigh and drumstick (Malgorzata *et al.*, 2005). The cooking loss was expressed as a percentage of weight of raw meat relative to the weight of the cooked meat.

$$\text{Cooking loss \%} = \frac{\text{Weight of raw meat (g)} - \text{Weght of cooked meat (g)}}{\text{Weight of raw meat (g)}} \times 100$$

The thermal shortening was determined by using freshly cut breast, thigh and drumstick meat sliced of 6 cm long respectively. The meat samples were subjected to heat (in boiling water of 100 ±1 ºC) for 20 minutes. The final lengths of the meat samples were taken after cooling to room temperature (25 ±1 ºC). Thermal shortening was expressed as a percentage of initial length of meat samples before cooking relative to its length after cooking (Apata *et al*., 2015).

$$\text{Thermal shortening (\%)} = \frac{\text{Initial lenght before cooking (cm)} - \text{Lenght after cooking (cm)}}{\text{Initial lenght before cooking (cm)}} x\ 100$$

The Water Holding Capacity (WHC) was determined by the press method as described (Suzuki *et al*., 1991). The 2g of meat sample was place in the filter paper (11 cm in diameter Whatman filter paper) and press in a glass by a pressing device for 1 minute. The compressed

meat samples were oven dried at 60°C for 48 hours to determine the moisture content which was the difference between the initial and the final weight. Tracing sheets were placed on the filter papers to trace two areas out which were the areas of pressed meat samples and area of exudates. The quantities of water released were measured as follows:

$$WHC\ \% = 100 - \frac{[(Ar - Am) \times 9.47]}{Wm \times Mo} \times 100$$

Ar = Area of water released from meat (cm^2)
Am = Area of meat sample (cm^2)
Wm = Weight of meat sample in (mg)
Mo =Moisture content of meat (%)

Sensory meat quality attributes

The sensory quality attributes evaluated were: colour, flavour, taste, texture, juiciness and overall acceptability based on 9-point hedonic scale rating (Table 1). There were 10 semi-trained panelist that were used for the sensory evaluation.

Table 1: 9-point hedonic scale

	Quality attributes					
Point	**Colour**	**Flavour**	**Taste**	**Texture**	**Juiciness**	**Overall acceptability**
1	Extremely dark	Extremely perceptible	Extremely bitter	Extremely coarse	Extremely dry	Dislike extremely
2	Just dark	Very perceptible	Just bitter	Very coarse	Very dry	Dislike very much
3	Moderately dark	Moderately perceptible	Moderately bitter	Moderately coarse	Moderately dry	Dislike moderately
4	Slightly dark	Slightly perceptible	Slightly bitter	Slightly coarse	Slightly dry	Dislike slightly
5	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
6	Slightly light	Slightly strong	Just sweet	Slightly fine	Slightly juicy	Like slightly
7	Moderately light	Moderately intense	Moderately sweet	Moderately fine	Moderately juicy	Like moderately
8	Very light	Strongly intense	Very sweet	Very fine	Very juicy	Like very much
9	Extremely light	Extremely intense	Extremely sweet	Extremely fine	Extremely juicy	Like extremely

Source: Adopted after Heinz and Hautzinger (2007).

3. RESULTS AND DISCUSSION

Freezing as a preservative method employed in this study aided in maintaining the quality of the chicken meat. This is evident in the reduction in thaw loss, WHC and cooking loss obtained from stored meat in this study.

The thaw loss of breast, thigh and drumstick in T2 (breast: 6.21%; thigh: 2.30%; drumstick: 1.90%) were significant ($p>0.05$) lower compared to those of T3 (thigh: 5.84%), T4 (breast: 8.08%; thigh: 6.43%) and T5 (breast: 8.26%; thigh: 6.82%; drumstick: 5.50%) as presented in Table 2. Notably, the thaw loss increased gradually as storage period increases with a significant increase between meat samples (from the breast, thigh and drumstick) stored for 7 days (1 week) and those stored for

28 days (4 weeks). The optimum significant increase in the thaw loss observed for meat samples of the breast and thigh was observed between the storage period of 7 days (1 week) and 21 days (3 weeks). Conversely, the drumstick meat samples had the least increase in thaw loss as such the only increment observed has been significantly different was between those samples stored for 7 days (week 1) and 28 days (week 4). This trend could be due to the increased number of the connective tissue in the drumstick than those of the breast and thigh meat samples. The increased thaw loss was due to storage period in the cold room which led to reduction in moisture content of the meat samples. This phenomenon was also observed by Qiaofen and Da-wen (2005) in their report on the "Application of Partial least squares regression (PLSR) in correlating physical and chemical properties of pork ham with different cooling methods" that decrease in moisture content could be responsible for the increased thaw loss during meat thawing.

Table 2: The effect of cold storage on thaw loss of broiler chicken meat stored for 4 weeks at -20ºC

	Treatments					
Variables (%)	T1 (fresh)	T2 (1 week)	T3 (2 weeks)	T4 (3 weeks)	T5 (4 weeks)	SEM
Breast	NA*	6.21^{b}	7.76^{b}	8.08^{a}	8.26^{a}	0.52
Thigh	NA*	2.30^{b}	5.84^{b}	6.43^{b}	6.82^{a}	1.63
Drumstick	NA*	1.90^{b}	2.92^{bc}	3.76^{ab}	5.50^{a}	0.70

$^{a, b, c, d}$Means on the same row with different superscripts are significantly different. SEM: Standard Error of Mean. *NA: Not applicable as meat samples were fresh and not stored.

The cooking loss of breast, thigh and drumstick in T1 (breast: 14.59%; thigh: 20.85%; drumstick: 13.32%) were significantly ($p>0.05$) lower compared to those of T2 (breast: 21.72%; drumstick: 17.30%), T3 (breast: 22.6%; thigh: 24.44%; drumstick: 20.27%), T4 between meat samples (from the thigh and drumstick) stored for 1 week and 3 weeks. This trend could be due to enzymatic reaction by ionic sublimation which aids in disintegrating the myofibril protein and the connective tissue (Bruce *et al.*, 2004). It was observed that (breast: 22.10%; thigh: 24.64%; drumstick: 22.61%) and T5 (breast: 21.08%; thigh: 25.06%; drumstick: 25.50%) as shown in Table 3. There was an increase in cooking loss as the storage period increases with a notable significant increase cooking loss did not increase significantly over storage period in breast meat samples. Although fresh un-stored breast meat had a significantly least value of cooking loss when compared to stored breast meat samples.

Table 3: The effect of cold storage on cooking loss of broiler chicken meat stored for 4 weeks at -20ºC

	Treatments					
Variables (%)	T1 (Fresh)	T2 (1 week)	T3 (2 weeks)	T4 (3 weeks)	T5 (4 weeks)	SEM
Breast	14.95^{b}	21.72^{a}	22.26^{a}	22.10^{a}	22.08^{a}	1.02
Thigh	20.85^{b}	23.01^{b}	24.44^{b}	24.64^{a}	25.06^{a}	1.80
Drumstick	13.32^{d}	17.30^{c}	20.27^{bc}	22.61^{ab}	25.50^{a}	1.21

$^{a, b, c, d}$Means on the same row with different superscripts are significantly different. SEM: Standard Error of Mean.

The thermal shortening of breast, thigh and drumstick had the highest value in T5 (breast: 30.67%; thigh: 34.67%; drumstick: 54.67%) been significantly ($p<0.05$) different from T1 (breast: 28.00%, thigh: 25.00%; drumstick: 33.00%), T2 (thigh: 27.33%; drumstick: 36.67%) and T3 (thigh: 29.33%; drumstick: 38.33%) as shown in Table 4. The thermal shortening in the meat samples increased over the storage periods with a significant increase observed in meat samples (from the thigh and drumstick) between 1 week and 3 weeks. This could be that cold storage increased the amount of water in the myofibril and with increase in the storage period the level of water in the myofibril increases causing the myofibrils to link to one another and to the cell membrane via proteinous connection leading to reduction in the diameter of the myofibril (muscle cell) during thermal application. This phenomenon harmonized with the observation made by Rahman *et al.*, (2014) in a study involving repeated free-thaw cycles on beef quality and safety.

Table 4: The effect of cold storage on thermal shortening of broiler chicken meat stored for 4 weeks at -20ºC

Variables (%)	Treatments					SEM
	T1 (Fresh)	T2 (1 week)	T3 (2 weeks)	T4 (3 weeks)	T5 (4 weeks)	
Breast	28.00^{b}	28.67^{a}	28.67^{a}	28.67^{a}	30.67^{a}	0.93
Thigh	25.00^{b}	27.33^{b}	29.33^{b}	32.00^{a}	34.67^{a}	1.47
Drumstick	33.00^{b}	36.67^{b}	38.33^{b}	53.33^{a}	54.67^{a}	2.27

$^{a, b, c, d}$Means on the same row with different superscripts are significantly different. SEM: Standard Error of Mean.

The WHC for breast, thigh and drumstick was highest in T1 (breast: 79.03%; thigh: 80.10%; drumstick: 78.16%) been significantly ($p<0.05$) different from T3 (breast: 57.70%; thigh: 66.33%), T4 (breast: 52.80%; thigh: 56.66%; drumstick: 63.39%) and T5 (breast: 49.03%; thigh: 52.06%; drumstick: 62.96%) as shown in Table 5. It was observed that water holding capacity obtained in meat stored for 4 weeks (28 days) decreases with storage days and this was significantly decreased as observed in thigh meat samples stored between 1 week (7 days) and 2 weeks (14 days). This trend is similar to the report of Chowdhury *et al.* (2006) that water holding capacity of frozen chevon decreases from 18.06% to 3.24% over 15 days of freezing preservation.

Table 5: The effect of cold storage on water holding capacity of broiler chicken meat stored for 4 weeks at -20ºC

Variables (%)	Treatments					SEM
	T1 (Fresh)	T2 (1 week)	T3 (2 weeks)	T4 (3 weeks)	T5 (4 weeks)	
Breast	79.03^{a}	76.66^{a}	57.70^{b}	52.80^{b}	49.03^{b}	3.75
Thigh	80.10^{a}	76.46^{a}	66.33^{b}	56.66^{c}	52.06^{c}	3.09
Drumstick	78.16^{a}	77.43^{ab}	70.87^{b}	63.39^{b}	62.96^{b}	2.40

$^{a, b, c, d}$Means on the same row with different superscripts are significantly different. SEM: Standard Error of Mean.

The sensory quality attributes of food products to any food processing technology is crucial in evaluating consumer acceptability. The sensory quality attributes analysed for the meat samples stored at ambient temperature of – 20^{o}C in a cold room for 28 days (4 weeks) are presented in Table 6. The results obtained indicated that there were significant variations ($p < 0.05$) in all the sensory parameters evaluated. With regards to flavour of thigh meat had the highest preference ('almost slightly strong' according to the 9-point hedonic scale) value in T1 (5.50) been significantly ($p<0.05$) higher compared to T3 (4.07), T4 (3.73) and T5 (3.57) but T1 was not significantly different from T2 (5.23). Physiologically, the process of flavour detection involves four basic sensations including saltiness, sweetness, sourness and bitterness by the nerve endings of the surface of the tongue (Iheagwara and Okonkwo, 2016). This result indicated that the flavour of thigh meat freshly un-stored (T1) and those stored for 1 week (T2) were higher probably because there was no thaw loss in freshly un-stored meat and for meat stored for 1 week where lower thaw loss was reckoned with when compared to those stored for 2, 3 and 4 weeks.

The juiciness of the thigh and drumstick meat samples had the highest preference ('Slightly juicy' according to the 9-point hedonic scale) value in T1 (thigh: 6.43 and drumstick: 6.37) been significantly ($p<0.05$) higher in comparison to those of T3 (thigh: 5.27), T4 (thigh: 3.93 and drumstick: 4.13) and T5 (thigh: 4.67 and drumstick: 5.20) while the juiciness of the thigh and drumstick meat sample had the same (non-significant; $p>0.05$) preference level ('*slightly juicy'* according to the 9-point hedonic scale) values in T1 (thigh: 6.43; drumstick: 6.37) and T2 (thigh: 6.10; drumstick: 6.33) respectively as shown in Table 6. The meat juiciness is an important constituents of meat tenderness, texture and taste and it has two major mode of indicators viz: first is the perception of wetness produced by the release of fluid from the meat when the meat is chewed for few seconds, while the second is the more sustained juiciness that apparently results from the stimulating effect of fat on the production of saliva in the mouth (Omojola *et al.,* 2003). In harmony with the first mode of indicator of juiciness in terms of the 'wetness produced from the meat'; this could be attributed to the higher preference for juiciness reckoned in freshly un-stored and those stored for 1 week probably because there were higher water holding capacity in freshly un-stored meat and for meat stored for 1 week when compared to those stored for 2, 3 and 4 weeks.

The sensory quality of breast, thigh and drumstick in terms of overall acceptability had the highest preference ('like moderately' on the 9-point hedonic scale rating) value in T1 (breast:7.27; thigh: 7.10; drumstick: 7.26) been significantly ($p<0.05$) higher compared to T2 (drumstick: 6.77), T3 (breast: 6.03; thigh: 5.87; drumstick: 6.00), T4 (breast: 6.23; thigh: 4.83; drumstick: 4.83) and T5 (breast: 5.23; thigh: 4.83; drumstick: 5.53) as shown in Table 6. The sensory evaluation (colour, taste, flavor, texture, Juiciness and overall acceptability) analysis showed a similar trend on the 9-point hedonic scale in terms of preference value with increasing storage period the preference value tends from "*like moderately"* to less preference value of "*dislike slightly".* Considering the overall acceptability of the sensory meat quality attributes; meat stored for 1 week was equally preferred to the fresh un-stored meat as adjudged by the taste panelist.

Table 6: The effects of cold storage on the sensory evaluation of broiler breast, thigh and drumstick stored for 4 weeks at -20^{o}C

Parameters	Primal cuts	Treatments					SEM
		T1 (Fresh)	T2 (1 week)	T3 (2 weeks)	T4 (3 weeks)	T5 (4 weeks)	
Colour	Breast	7.53^{a}	7.17^{a}	6.53^{b}	5.87^{c}	5.40^{c}	0.24
	Thigh	6.77^{a}	6.27^{a}	5.13^{b}	5.07^{b}	4.06^{c}	0.23
	Drumstick	7.47^{a}	6.00^{b}	5.43^{bc}	5.63^{bc}	5.07^{c}	0.24
Flavour	Breast	5.93^{a}	5.37^{a}	5.33^{ab}	5.17^{b}	4.73^{b}	0.18
	Thigh	5.50^{a}	5.23^{a}	4.07^{b}	3.73^{b}	3.57^{b}	0.24
	Drumstick	5.77^{a}	5.63^{a}	5.53^{a}	5.47^{ab}	4.60^{b}	0.2
Taste	Breast	7.33^{a}	6.40^{ab}	5.97^{b}	5.87^{b}	4.57^{c}	0.24
	Thigh	7.00^{a}	6.13^{b}	6.10^{b}	4.13^{c}	3.93^{d}	0.38
	Drumstick	7.07^{a}	6.30^{b}	5.77^{bc}	5.67^{bc}	5.07^{c}	0.21
Texture	Breast	6.37^{a}	6.06^{a}	5.47^{b}	6.27^{ab}	4.93^{b}	0.23
	Thigh	6.43^{a}	5.27^{b}	6.10^{a}	3.39^{b}	4.67^{b}	0.26
	Drumstick	6.80^{a}	6.83^{a}	5.53^{b}	5.23^{b}	5.43^{b}	0.23
Juiciness	Breast	6.80	6.77	6.57	6.30	6.17	0.27
	Thigh	6.43^{a}	6.10^{a}	5.27^{b}	4.67^{bc}	3.93^{c}	0.29
	Drumstick	6.37^{a}	6.33^{a}	5.40^{ab}	5.20^{b}	4.13^{c}	0.31
Overall acceptability	Breast	7.27 ^{a}	7.00^{a}	6.23^{b}	6.02^{bc}	5.23^{c}	0.23
	Thigh	7.10^{a}	7.00^{a}	5.87^{b}	4.83^{c}	4.83^{c}	0.28
	Drumstick	7.67^{a}	6.77^{b}	6.00^{c}	5.53^{d}	4.83^{d}	0.28

$^{a, b, c, d}$Means on the same row with different superscripts are significantly different. SEM: Standard Error of Mean.

4. CONCLUSION

Based on this experimental result, cold storage had no adverse effect on the physical and sensory quality attributes of broiler chickens. However, it is recommended that broiler meat should not be stored more than one week in the cold room for optimal processing yield and consumers' preference for freshness in terms of the sensory meat quality.

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