Saccharomyces cerevisiae-derived prebiotic as a sustainable bioactive substance for improving broiler meat quality

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SUMMARY

This study aimed to investigate the effect of supplementation with a commercial prebiotic based on a *Saccharomyces cerevisiae* derived-prebiotic on meat quality traits of broiler chicken. A total of 192 male chicks Arbor Acres were divided into four groups with six replicates each and were housed in cages (8 birds/cage). The first group (T0) was unsupplemented and considered as a positive control. The experimental groups supplemented with three increasing levels of prebiotic (T1=1; T2=1.5 and T3=2 g of prebiotic per kg of basal diet) and the prebiotic was removed from the diet one week. At the end of the 6 weeks, the birds were slaughtered, dressed, and subjected to quality analyses. Breast muscle pH was measured at 0h, 2h, 6h, and 24h after slaughter. The color values of the CIE Lab Color System (skin, breast, and thigh) were determined 24h post-mortem. Sensory analysis was conducted to evaluate flavor, texture, juiciness, and global acceptance of chicken breast meat from broilers fed prebiotic. The groups fed with prebiotics showed higher pH values of breast muscle at 0 and 2 hours post-mortem ($P < 0.05$), but not at pH 6 hours and ultimate pH among all samples ($P > 0.05$). Inclusion prebiotics induced significant decreases in the breast "lightness L*" compared to the control group. However, no significant changes ($P > 0.05$) were observed in the skin breast and thigh. An increase in a* (redness) value and a decrease in b* (yellowness) value were observed in all supplemented groups, in comparison with controls. A significant decrease in b* (yellowness) values were observed in all parts of supplemented samples (skin, thigh, and breast). Sensory analysis showed that supplementation with prebiotic at the higher dose (2 g/kg) has significantly improved global hedonic acceptance. This study highlighted that using *Saccharomyces cerevisiae* derived-prebiotic in the broiler diet may be a beneficial and natural tool for improving meat quality.

KEY WORDS

Prebiotic, pH, color, sensory characteristics, meat, broiler.

INTRODUCTION

Poultry production had socio-economic and cultural values in most developing countries including Tunisia. Poultry meat is not only a valuable source of high-quality proteins but also of minerals and vitamins[1]. Many studies reported that the level of those compounds, as well as meat quality, is determined not only genetically, but it is also affected by environmental factors and especially on the content of feeds[2]. Nevertheless, the use of antibiotics as growth promoters (AGPs) faces serious objections such as antibiotic-resistant pathogens and drug residues in poultry products, which can affect public health[3]. Therefore, antibiotics are being taken out of poultry diets around the world and have been prohibited by many countries as AGPs[4]. This ban contributed to increased incidence of enteric diseases, poor growth performance, and therefore serious economic damage[5]. The focus of alternatives to replace antibiotics has gained increasing interest in animal nutrition in recent years[6]. Moreover, consumers are becoming more mindful of animal production systems, and in particular the feeding, since antibiotics can impair their health. Particular concern has been paid to the use of prebiotics as a substitute for AGPs. Recent researches have focused on the importance of prebiotics as functional foods in poultry nutrition to sustain productivity and improve the quality of animal products in particular fatty acid profile and nutritional ratios of meat[7]. Prebiotic has been defined as a non-digestible food ingredient that improves the host's microbial balance. Several types of nondigestible oligosaccharides, such as fructooligosaccharides (FOS), galactooligosaccharides (GOS), mannan oligosaccharides (MOS) and isomalto oligosaccharides (IMO), are considered to be prebiotic and have been studied as sustainable alternatives to AGPs[8]. Although many studies have established the beneficial effects of prebiotics in maintaining gut health and promoting animal performance. However, there was a scarcity of studies on the impact of prebiotics administration on meat quality. Thus, the influence of prebiotics on meat quality improvement remains controversial. Further investigations are needed to clarify the effect of prebiotics administration on meat quality in broiler chickens. Among the prebiotics examined in broilers, yeast-based products derived from the strain *Saccharomyces cerevisiae* have been shown to improve animal health and metabolism as well as to decrease morbidity, thereby enhancing the growth performance[9, 10]. Moreover, Askri et al.[11] have confirmed the favorable effects of inclusion

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on different levels of *Saccharomyces cerevisiae*-derived prebiotic in broiler diet on meat production. Taken together these data indicated that duration prebiotic inclusion has paramount importance since it can negatively affect meat sensory quality when prebiotic was given during the whole rearing period[9].
The present study aimed to evaluate the effects of a commercial *S. cerevisiae* derived prebiotic supplementation on meat quality traits in broiler chickens and consumers'acceptance.

MATERIALS AND METHODS

Birds and experimental design

All birds were individually identified, weighed, divided into four groups and were housed in individual cages. Birds received diet and water *ad libitum* throughout the rearing period. Daily observations were made about general flock condition, temperature, lighting, water, feed, and anticipated events in the house.

Diets and treatments

Diets are composed of corn and soybean meal and did not contain antimicrobial growth promoters or coccidiostats. The prebiotic product composed of Refined functional carbohydrates (RFC), including mannan oligosaccharides (MOS), β-glucan, and D-mannose which account for 20 to 30% of the cell dry mass, derived from the cell wall of *Saccharomyces cerevisiae*, with yeast culture (Arm & Hammer Animal and Food Production). The chicks received one of four treatments randomly as follows: T0 was a positive control unsupplemented; T1; T2 and T3 were supplemented with 1; 1.5 and 2 g of prebiotic per kg of basal diet. The study of Askri et al.[9] revealed an unpleasant taste, attributed to a yeasty flavor when this prebiotic supplemented in broiler diet during the whole rearing period (six weeks). Based on these results, the prebiotic was given most of the rearing period (until the fifth week) and was removed one week before slaughter to avoid alteration of meat sensory quality. Slaughter survey at the age of six weeks, a total of 72 birds were randomly selected (18 from each group), weighed, and slaughtered. After evisceration and cutting, the dressed broilers (breast and thigh) were kept for different analyses.

pH measurement

The pH was measured at different time points post-mortem (0h; 2h; 6h and 24h) in the breast muscle at 2 cm depth using a calibrated pH meter equipped with a penetrating glass electrode (Hanna HI- 99163).

Color parameters

The CIE Lab color of skin and meat (breast and thigh) were determined at 24h post-mortem using a chromameter (CR410 Konica Minolta Sensing Inc., Osaka, Japan). The readings were taken on equivalent positions. The tip of the chromameter measuring head was placed flat against the surface of the skin or of the meat for breast and thigh. In this coordinate system, the L* value measures lightness, ranging from 0 (black) to +100 (white). The a* value ranges from –100 (green) to +100 (red), and the b* value ranges from –100 (blue) to +100 (yellow).

Sensory analysis

Sensory evaluation was performed by semi-trained panelists. The group of panelists who participated in the study was composed of 10 normal sighted persons, aged from 23 to 30 years. They were recruited at random from among students of the National Agronomic Institute of Tunisia. Only those selected who declared that their senses of taste and smell were not debilitated and that they consumed poultry meat at least once a week. They were informed that the aim of the experiment was poultry meat, but did not know the species of birds or the type of meat being evaluated. Breast samples were cooked in a pre-warmed oven (180ºC) until the internal temperature reached 75ºC. The samples were standardized (size, codification, and tasting temperature) and evaluated by the sensory panel. Each panelist was asked to evaluate cooked breast samples according to the following attributes: color intensity, odor, fat and strange flavor, tenderness, juiciness, and global acceptance. They were scored in a 10-point scale for organoleptic quality that is, excellent 10; good 8-9; fair 6-7; marginal acceptable 4-5; unacceptable 2-3; bad 0-1[12].

Statistical analysis

Statistical analysis were performed using Statistical Analysis Software for Windows SAS 9.4[13]. Data were analyzed using the GLM procedure, where treatment was the main factor. Prior analysis the residuals of the traits were tested for normality. Dunnet's test was applied to compare every mean to a control mean. Additionally, regression (linear, cubic, and quadratic) models were run to study dose-dependent responses. All values were expressed as a statistical means± standard error. The overall level for statistical significance was set at $P<0.05$.

RESULTS

The variation of post-mortem pH value in the muscle breast of different groups of broilers is depicted in Table 1. Our results indicated that prebiotic supplementation has increased the post-mortem pH values of breast muscle at 0 and 2 hours, post-mortem, but no significant increase was noticed at 6 and 24h post-mortem. For all the supplemented groups, pH tended to increase over time.

Table 1 - Effect of prebiotic supplementation at different levels on breast meat pH *post-mortem.*

pH	T0 (Control)	T1 (1 g/kg)	T2 (1.5 g/kg)	T3 (2 g/kg)	*P-Value* (ANOVA)	*p-values of regression model*		
						Linear	Quadratic	Cubic
0 h	5.80±0.12^{b}	5.85±0.11^{a}	5.92±0.14^{a}	5.86±0.17^{a}	0.049	0.056	0.048	0.041
2 h	5.76±0.45^{b}	5.79±0.14^{b}	5.82±0.15^{ab}	5.86±0.12^{a}	0.037	0.041	0.052	0.039
6 h	5.71±0.25	5.72±0.18	5.74±0.19	5.73±0.20	0.628	0.194	0.417	0.628
24 h	5.68±0.09	5.70±0.19	5.72±0.11	5.73±0.13	0.892	0.898	0.890	0.892

$^{a-c}$ Means within a row with different superscripts are significantly different ($P<0.05$). Values represent the Mean ± SEM.

The results of the color characteristics were presented in Table 2. Supplementation prebiotic induced significant decreases in the breast "lightness L*". Nevertheless, no significant changes (P>0.05) were observed in the skin breast and thigh "lightness L*". Interestingly, an increase in a* (redness) values in thigh and breast samples were observed. Indeed, all thigh supplemented samples had a higher redness value compared with control one, but the significant increase was noticed only in T1 and T3 samples (P<0.05). Besides, redness of breast samples was significantly higher in all supplemented samples (T0=6.74; T1=7.22; T2=7.12; T3=7.04). A significant decrease in b* (yellowness) values were observed in all parts of supplemented samples (skin, thigh, and, breast).

As shown in Table 3, supplementation with *Saccharomyces cerevisiae*-derived prebiotic has modified breast meat sensory parameters, in terms of tenderness, juiciness, and taste scores (P<0.05). However, no significant differences were found (P>0.05) between control samples and those from chicken fed increasing doses of prebiotic, for odor, color, and flavor (P>0.05), indicating that supplementation with *Saccharomyces cerevisiae* as prebiotics had no negative effect on these sensory characteristics. Interestingly, the incorporation of *Saccharomyces*-derived prebiotic at a higher dose (2 g/kg) has significantly improved taste scores (Table 3). Therefore, this result confirmed our hypothesis that pulling out prebiotic one week before slaughtering could reduce or even remove the unpleasant taste, attributed to a yeasty flavour[19].

DISCUSSION

The meat pH is currently used for the assessment of meat quality, processing suitability, and hardness[14]. The pH values reported in our study entirely fit within those reported in the study of Lipi ski et al.[15]. Similarly, Rehman et al.[16] reported an increase in pH at 0 and 2 h post-mortem. Alteration in pH during *rigor mortis* is an indicator of some biochemical processes (protein denaturation) to transform muscle into the meat[17]. Therefore, this difference in muscle pH at 0 and 2 hours post-mortem suggest different metabolic changes related to prebiotic administration. This change in pH can affect meat quality characteristics, such as color, texture, and water-holding capacity (WHC).

In the present study, supplementation of increasing doses of prebiotic in broiler diet did not significantly affect ultimate pH. Accordingly, Maiorano et al.[18] reported that galactooligosaccharides prebiotic delivered *in ovo* did not affect the ultimate pH of the pectoral muscle (P > 0.05). Konca et al.[19] evaluated the effects of prebiotic in finishing turkey diets on meat pH value and also reported that dietary treatment did not affect the pH value at 24 h of post-mortem period. Moreover, similar pH values (P > 0.05) were observed among experimental groups delivered trans-galactooligosaccharides *in ovo*[14]. Conversely, Cheng et al.[20] showed elevated breast muscle pH value at 24 h post-mortem in broilers with the incorporation of synbiotic (P < 0.05), whereas Sang-Oh and Byung-Sung[21] showed a sig-

Table 2 - Effect of prebiotic supplementation at different levels on meat and skin color characteristics of broilers.

		T0 (Control)	T1 (1 g/kg)	T2 (1.5 g/kg)	T3 (2 g/kg)	*P-Value* (ANOVA)	*p-values of regression model*		
							Linear	Quadratic	Cubic
Skin	L	65.06±2.22	65.19±2.34	64.07±2.13	63.74±2.24	0.072	0.091	0.093	0.098
	a	4.18±1.52^b	4.18±1.67^b	4.56±1.27^a	4.00±1.21^b	0.035	0.046	0.043	0.041
	b	24.12±2.33^a	23.49±2.51^b	23.09±2.37^b	23.19±2.42^b	0.037	0.041	0.052	0.039
Thigh	L	59.28 ±3.24	57.59±3.17	58.51±3.61	58.38±2.48	0.628	0.194	0.417	0.628
	a	8.89±1.25^b	9.47±1.37^a	8.93±1.72^b	9.06±0.93^a	0.041	0.052	0.089	0.092
	b	13.02±1.25^a	11.40±2.73^b	12.03±2.43^{ab}	11.45±1.71^b	0.049	0.056	0.048	0.041
Breast	L	61.90±2.68^a	59.8±2.37^b	60.52±2.82^{ab}	60.18±3.47^b	0.037	0.048	0.052	0.039
	a	6.74±1.13^b	7.22±0.91^a	7.12±1.31^a	7.04±1.12^a	0.049	0.194	0.417	0.628
	b	14.74±1.91^a	13.09±2.32^b	13.01±1.73^b	12.7±2.53^c	0.047	0.059	0.079	0.087

L: Lightness; a: redness; b; yellowness; a-c Means within a row with different superscripts are significantly different (*P* <0.05). Values represent the Mean ± SEM.

Table 3 - Effect of prebiotic supplementation at different levels on sensory scores and global acceptance of meat broilers.

	T0 (Control)	T1 (1 g/kg)	T2 (1.5 g/kg)	T3 (2 g/kg)	*P-Value* (ANOVA)	*p-values of regression model*		
						Linear	Quadratic	Cubic
Odour	4.00±2.14^a	3.75±1.91^a	4.25±1.04^a	3.75±1.38^a	0.923	0.920	0.832	0.514
Colour	2.75±2.12^a	3.75±1.39^a	4.62±1.51^a	3.62±1.60^a	0.206	0.195	0.099	0.514
Tenderness	3.00±1.93^c	4.12±1.36^b	5.00±1.93 ^{a}	3.62±0.51^{bc}	0.028	0.089	0.297	0.419
Juiceness	3.00±1.31^b	3.12±0.83^b	4.00±1.60^a	4.50±2.07^a	0.028	0.174	0.726	0.643
Taste	2.87±0.99^c	3.87±2.42^b	4.50±1.51^a	5.00±1.92^a	0.017	0.123	0.691	0.930
Flavor	3.37±2.39^a	3.87±2.10^a	4.12±1.46^a	4.12±1.35^a	0.391	0.836	0.704	0.956
Global acceptance	3.75±1.67^b	3.62±1.30^b	5.62±2.00^a	6.62±1.30^a	0.001	0.002	0.331	0.225

$^{a-c}$ Means within a row with different superscripts are significantly different (*P* <0.05). Values represent the Mean ± SEM.

nificant decrease on chicken meat ultimate pH after administration of dietary inulin prebiotic. The pH measurements at 24 h, at the end of the post-mortem process, were found to be within the acceptable range for commercial meats[22]. Based on the results from the present study, it can be postulated that the beginning of the onset of rigor mortis was around 6 hours post mortem. According to Hwang et al.[23], muscle pH during the onset of rigor mortis, and ultimate pH have a significant effect on meat quality because these imply the rate of post mortem metabolism in muscle tissue, and subsequently govern protein denaturation and water-holding capacity. Watanabe et al.[24] have reported that the ultimate pH of muscle is a key element of meat quality and is related to the reduction of glycogen and liberation of lactic acid pre- and post-slaughter.

The current findings are in line with the results of Akiba et al.[25] who observed an increase in redness value in the breast and thigh muscles of broilers when feed supplemented with yeast *Phaffia rhodozyma*. Similarly, Cho et al.[26] have observed an increase in breast meat redness in broilers receiving prebiotic diets, whereas L* and b* values were not affected. As reported by Pelicano et al.[27] using *Saccharomyces cerevisiae*, redness (a*) was significantly higher ($P<0.05$) in treated groups. Konca et al.[19] revealed that mannan-oligosaccharides did not affect meat pigmentation of finishing turkeys. Several studies have established a correlation between ultimate pH and CIE Lab color indexes. A lower pH in breast meat can lead to a pale color and low WHC[15]. According to Jiang et al.[28], higher a* value was considered as the most appreciated by consumers and lower b* value indicated less pale meat.

Our results indicated a positive effect of *Saccharomyces cerevisiae*-derived prebiotic on meat tenderness (Table 3). Similarly, Zhang et al.[29] showed that meat tenderness has been improved by the incorporation of whole yeast or *Saccharomyces cerevisiae* extract in broiler diet. Likewise, increased tenderness of breast muscle in broilers fed mannan oligosaccharides (prebiotics) was found by Abdel-Raheem & Abd-Allah[30]. As reviewed by Mir et al.[31], texture constitutes one of the most important quality attributes, associated with consumers' satisfaction in the eating quality of poultry. Furthermore our results clearly showed that supplementation with prebiotic at a higher dose (2 g/kg) has significantly improved global acceptance (Table 3). Gardzielewska et al.[32] have also shown that the addition of oligosaccharides (prebiotics) to broiler diets led to better sensory characteristics. However, no significant correlations were found between global acceptance and quality parameters (ultimate pH, Lab indexes). In terms of product color, although no significant difference was found in sensory color scores, our data are in agreement with those of Yang et al.[33] indicating that an increase of a* value could improve consumers' acceptance.

To the best of our knowledge, there have been limited researches on the impact of prebiotics on meat organoleptic and sensory quality of broilers. Moreover, incorporation of *S. cerevisiae* into the diet enhanced color/appearance, flavor/taste, odor and juiciness, and overall acceptability of broiler meat[34]. Janocha et al.[35] have also shown that mixtures containing *Saccharomyces* positively influenced meat flavor. Cho et al.[26] revealed an improvement of moisture loss in breast meat from chickens receiving β-glucan (Agrobacterium sp.) and kefir (a fermented milk product) combined supplementation. On the other hand, Pelicano et al.[27] using *S. cerevisiae* in drinking water and diet have pointed out the preservation of meat sensory quality after feeding broilers with probiotics.

CONCLUSION

Saccharomyces cerevisiae-derived prebiotic preparations are an interesting source in poultry production systems. They are natural supplements and therefore no need grace period. Our study has shown that supplementation of broilers diet by a commercial *Saccharomyces cerevisiae*-derived prebiotic at a dose of 2 g/kg has improved post-slaughter quality indicators.

Using prebiotic has significantly increased pH just after slaughtering at doses up to 2 g/kg and 6 hours after the slaughter at a dose of 2 g/kg.

Interestingly, it did not negatively affect ultimate pH, an extremely important parameter for consumers. Moreover, prebiotic administration has improved meat instrumental color, by increasing redness (a*) and reducing yellowness (b*). Sensory analysis has indicated significant changes in breast meat taste and tenderness, and preservation of odor, color, juiciness, and flavor, leading to a significant improvement of consumers' global acceptance of breast meat from supplemented animals.

In conclusion, this study revealed that *Saccharomyces*-derived prebiotic at a dose of 2 g/kg added to broiler diets is recommended not only to improve animal performances as shown previously (Askri et al., 2020) but also to provide a better meat quality, thereby increasing the profitability of these animals. Further studies in both experimental and commercial settings are needed to understand the extent of this contribution, and in particular to assess the mechanisms of action of prebiotics.

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