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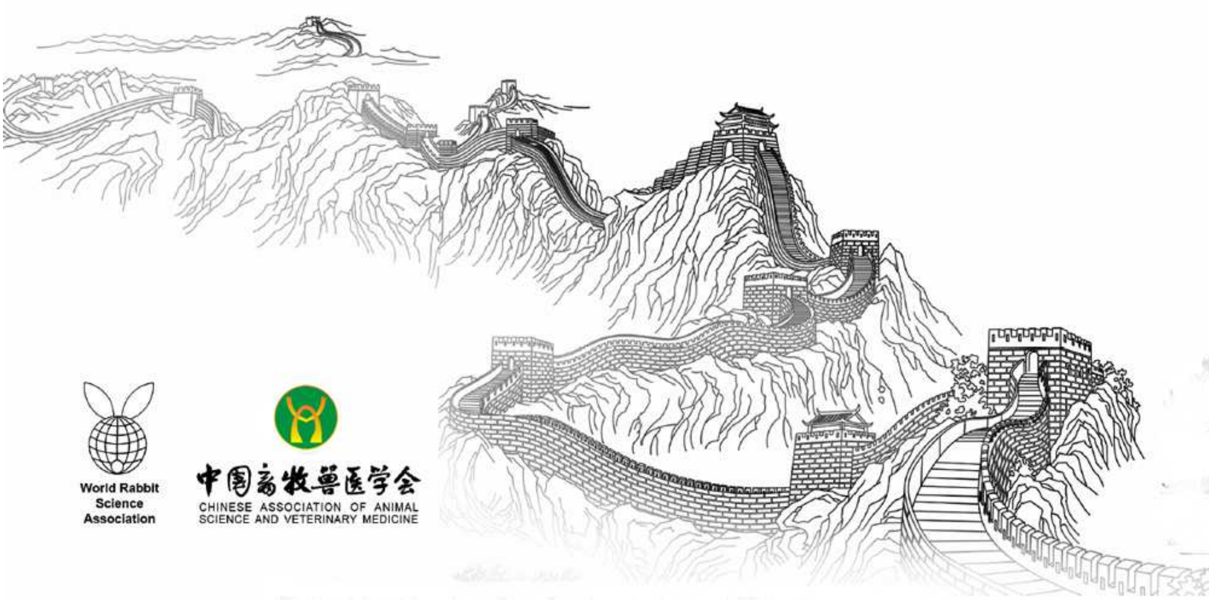

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EFFECTS OF DIETS WITH INCREASING LEVELS OF CITRUS PULP ON MEAT QUALITY AND FATTY ACID COMPOSITION OF GROWING RABBITS

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ABSTRACT

This study analyses the effects of diets containing four inclusion levels of citrus pulp on the quality and composition of *longissimus lumborum* and the hind leg meats in growing rabbits. The *longissimus lumborum* had a lower ultimate pH than the hind leg. The latter had higher moisture, crude fat and cholesterol as compared to the *longissimus lumborum* meats. The hind leg meats had a lower proportion of C18:1n-9 and C20:4n-6 and a higher percentage of C16:0 and C18:2n-6 than the *longissimus lumborum* . Citrus pulp diets increased meat ultimate pH and reduced the water holding capacity as compared to the control diet. Meat from animals given citrus pulp had lower crude protein and moisture and higher cured fat and cholesterol content in comparison to that from the control group. The proportions of intramuscular unsaturated and polyunsaturated fatty acids were higher in the citrus pulp group as compared to the control one. In particular, 14% citrus group showed the highest crude protein content, unsaturated and polyunsaturated fatty acids percentages than other experimental groups. Overall, the use of a citrus pulp included in rabbit diets did not reduced quality and, therefore, it seems to be a possible ingredient to promote the exploitation of citrus by-product and reduce feeding costs.

Keywords: Citrus pulp; Rabbit; The longissimus lumbborum meat; The hind leg meats; Meat quality; Fatty acids

INTRODUCTION

In the last 50 years, word rabbit meat production has increased by 2.5-fold up to about 1.7 million tons in 2011. China is currently the world's leading producer (700, 000 t/year). Currently, rabbit is in need of nearly 10 million tons a year of feed in China. There is a huge pressure on a steady supply of conventional fodder. Hence, it is critical to develop unconventional fodder resources. Chongqing is not only the major producer of rabbit meat products but also the native haunt of the citrus in China. Based on these considerations, making full use of citrus pulp feed fed rabbits can reduce feed costs and promote the development of rabbit farming. The objective of this study was to evaluate the use of citrus pulp in rabbit diet and the effect on meat quality, with an emphasis on intramuscular fatty acid composition.

MATERIALS AND METHODS

Experimental design

At 45 days of age, eighty Ira rabbits were divided into four homogeneous groups and fed one of four experimental diets for 30 days, at which time the rabbits were 75 days old. Animals were kept under controlled environmental conditions (at room temperature 25 °C, a relative humidity of ca 65% and 12 h of light per day) and two rabbits per cage. During the study, rabbits were fed two times a day and free drinking water. At the end of experiment (75 days of age), all rabbits were fasted 24 h before slaughter. The carcasses were prepared by removing the skin, feet, paws, genital organs, urinary bladder and digestive tract, as recommended by Blasco et al. (1993). Hot carcasses were immediately chilled at 4 °C. After 24 h of storage at 4 °C, the *longissimus lumborum* muscles and the hind leg meats were carefully dissected. All the samples were immediately frozen at -20 °C until analyzed.

Physical characteristics of rabbit meat

Ultimate pH (pHu) was measured at 24 h with a Knick digital pH meter (Broadly Corp, Sartorius AG, Germany) after homogenization of 1 g of raw muscle for 30 s in 10 mL of 5 M iodoacetate (Korkeala, Maki-Petais, Alanko, & Sorvettula, 1984).The water holding capacity (WHC) was determined with the modified methodology (Nakamura & Katoh, 1985). The sample (10g) was centrifuged for 30 min at 5000 g (5810, Eppendorf Company, Germany). After centrifugation, the sample was absorbed the surface moisture by filter paper and reweighed. The result was expressed as the percentage of moisture realized from the sample to the initial moisture content. Colour was evaluated on 2 cm-thick muscle slices cut 24 h post-mortem. Instrumental meat colour expressed as L^* (lightness), a^* (redness), b^* (yellowness) according to the CIE lab system (CIE, 1986) was measured with a Ultra S can PRO (light source: D_{65}, visual angle: 0°). Before measurement, each sample was allowed to bloom for 1 h. For each sample three measurements were taken perpendicularly to the cut surface of the muscle.

Cooking losses (%) were determined as follows: 2 cm-thick of muscle sample (10 g) was sealed in plastic bags and immersed in a water-bath at 70 °C until the core temperature reached 70 °C. Then the bags were cooled to room temperature, blotted dry with filter paper and reweighed. Cooking losses were then calculated by measuring the weight difference before and after cooking and expressed as a percentage.

Calculations and statistical analyses

The statistical analyses were performed using the SPSS (1999) software package (version 16.0 for windows, SPSS inc, USA). The data are presented as the least square means and least significant differences at 5%.

RESULTS AND DISCUSSION

Physical and chemical characteristics of rabbit meat

The physical and chemical traits of rabbit meat were shown in Table 1. Ultimate pH of meats was lower ($p<0.05$) in the control samples as compared to the citrus pulp ones, probably because of the higher glycogen deposition in the control diet，consistent with previous study Lanza M (2004). However, Caparra et al. (2007) and Rodrigues et al. (2008) did not report a significant effect of dried citrus pulp diets on lamb meat ultimate pH. The hind leg showed a higher ($p<0.05$) ultimate pH as compared to the *longissimus lumborum*. D'Agata et al. (2009) showed the similar result in grey coloured Italy rabbits meat.

Table 1: Physical and chemical characteristics analysis of the *longissimus lumborum* (LL) muscles and the hind leg (HL) of rabbits (means ± S.E; n =10) fed experimental diets (% of citrus pulp)

	Control		Citrus 7%		Citrus 14%		Citrus 21%	
	LL	HL	LL	HL	LL	HL	LL	HL
Physical variables of muscles at 24 h post-mortem								
pHu	5.79^a	6.14^A	5.97^c	6.17^B	6.01^d	6.17^B	5.91^b	6.19^C
Lightness (L*)	$55.92±1.51^a$	$58.64±1.66^A$	$56.51±2.03^a$	$57.53±2.17^A$	$58.13±0.62^a$	$60.09±0.72^A$	$56.42±2.45^a$	$60.09±2.12^A$
Redness (a*)	$0.60±0.04^a$	$-0.41±0.08^A$	$0.36±0.02^b$	$-0.47±0.02^A$	$0.43±0.06^b$	$-0.51±0.06^B$	$0.40±0.08^b$	$-0.87±0.01^C$
Yellowness (b*)	$10.17±0.41^a$	$9.35±0.29^A$	$10.21±0.30^a$	$9.78±0.44^A$	$10.61±0.34^a$	$9.31±0.34^A$	$10.78±0.47^a$	$9.62±0.26^A$
WHC %	$73.66±0.89^a$	$72.80±0.26^A$	$72.23±1.05^{ab}$	$71.23±1.25^{AB}$	$71.05±0.64^b$	$69.16±0.72^B$	$71.01±0.82^b$	$68.72±0.82^B$
Cooking loss %	$17.44±0.55^a$	$12.31±0.10^A$	$19.76±0.26^b$	$15.16±0.34^B$	$23.66±0.49^c$	$19.39±1.01^C$	$24.00±0.82^c$	$20.05±0.62^C$
Proximate analyses								
Moisture %	$75.22±0.39^a$	$74.63±0.36^A$	$74.70±0.79^a$	$75.14±0.55^A$	$74.52±1.73^a$	$74.89±0.15^A$	$73.97±0.44^a$	$74.96±1.51^A$
Crude protein %	$21.86±0.07^a$	$21.83±0.44^A$	$20.73±0.08^b$	$20.38±0.10^B$	$21.44±0.58^{ab}$	$21.18±0.25^{AB}$	$20.34±0.52^b$	$20.21±0.74^B$
Crude fat %	$1.12±0.06^a$	$1.27±0.04^A$	$1.15±0.05^a$	$1.29±0.03^A$	$1.23±0.05^b$	$1.42±0.05^B$	$1.21±0.03^{ab}$	$1.53±0.06^C$
Cholesterol mg/100g	$65.43±1.80^a$	$72.82±2.78^A$	$65.14±1.74^a$	$70.99±2.39^A$	$66.93±3.14^a$	$70.88±3.87^A$	$66.90±2.62^a$	$69.63±2.98^A$

[a,b,c,d,A,B,C] Means in the same row with unlike superscripts differ $P<0.05$.

Meat lightness (L*) and meat yellowness (b*) were not affected by diet (p>0.05). The dietary treatment affected meat redness (a*), with higher values measured in meat from rabbits in the control group compared to citrus pulp groups (p<0.05). The Citrus 14% group has a highest L* values than other experimental groups. The L* value of LL muscles were lower than HL meats, but the value of a* and b* were higher. This difference can be explained by high ultimate pH possibly resulting in a dark colour (Sales & Mellet, 1996). Because of the difference of animal species, Inserra et al. (2014) reported that meat from lambs fed with conventional feedstuffs tended to be yellower than meat from lambs fed with citrus pulp. Cerisuelo et al. (2010) indicated that the meat colour have no effect of feeding pigs with citrus pulp.

Rabbits meat fatty acid composition

Table 2: Fatty acid content of the *longissimus lumborum* (LL) muscles and the hind leg (HL) of rabbits (means ± S.E; n =10) fed experimental diets (% of citrus pulp)

Fatty acid(% total FA)	Control		Citrus 7%		Citrus 14%		Citrus 21%	
	LL	HL	LL	HL	LL	HL	LL	HL
C14:0	1.23±0.08	1.22±0.02	1.17±0.01	1.56±0.06	1.24±0.03	1.26±0.03	1.34±0.04	1.71±0.01
C14:1n-6	0.51±0.01	0.51±0.01	0.48±0.01	0.50±0.01	0.55±0.02	0.56±0.02	0.58±0.02	0.62±0.01
C15:0	1.24±0.02	1.17±0.03	0.98±0.05	1.04±0.02	1.09±0.02	1.29±0.04	1.05±0.02	1.16±0.05
C16:0	27.45±0.46^{a}	28.25±0.06^{A}	27.37±0.10^{a}	27.55±0.28^{B}	26.98±0.22^{a}	27.06±0.14^{B}	26.89±0.18^{a}	27.32±0.48^{B}
C16:1n-7	0.54±0.01	0.74±0.01	0.63±0.02	0.88±0.01	0.23±0.01	0.25±0.02	0.80±0.02	0.89±0.02
C17:0	0.65±0.02	0.70±0.02	0.64±0.01	0.65±0.01	0.77±0.02	0.81±0.01	0.75±0.02	0.81±0.02
C17:1	0.64±0.02	0.58±0.04	0.55±0.02	0.41±0.01	0.72±0.03	0.67±0.02	0.93±0.05	0.45±0.04
C18:0	9.41±0.09^{a}	10.30±0.20^{A}	9.63±0.19^{a}	9.45±0.25^{B}	9.56±0.15^{a}	9.19±0.10^{B}	9.39±0.21^{a}	9.84±0.28^{AB}
C18:1n-9	19.18±0.08^{a}	18.18±0.05^{A}	18.28±0.18^{b}	18.18±0.22^{A}	17.34±0.12^{c}	16.47±0.08^{C}	17.64±0.15^{c}	17.77±0.14^{B}
C18:1n-7	0.47±0.01	1.04±0.01	0.55±0.01	1.14±0.02	0.87±0.03	0.85±0.07	0.70±0.01	1.01±0.03
C18:2n-6	24.65±0.31^{a}	24.66±0.18^{A}	24.50±0.12^{ab}	25.33±0.12^{B}	23.91±0.25^{b}	26.05±0.17^{C}	23.83±0.13^{b}	25.36±0.27^{B}
C18:3n-3	1.34±0.03^{a}	1.50±0.06^{B}	1.21±0.02^{b}	1.60±0.02^{C}	1.48±0.07^{c}	1.50±0.05^{B}	1.77±0.04^{d}	1.28±0.03^{A}
C20:0	0.46±0.02	0.10±0.01	0.09±0.01	0.08±0.01	0.09±0.02	0.09±0.01	0.09±0.01	0.09±0.01
C20:1n-9	0.16±0.01	0.21±0.01	0.19±0.01	0.22±0.01	0.21±0.01	0.19±0.01	0.20±0.01	0.21±0.02
C20:2n-6	0.16±0.01	0.14±0.01	0.37±0.02	0.32±0.02	0.15±0.01	0.13±0.01	0.38±0.01	0.31±0.02
C20:3n-6	0.58±0.02	0.69±0.02	0.72±0.01	0.62±0.03	0.72±0.03	0.73±0.02	0.79±0.01	0.58±0.01
C20:4n-6	7.56±0.12^{a}	6.08±0.19^{A}	8.55±0.21^{b}	7.19±0.17^{B}	9.34±0.33^{c}	8.35±0.25^{C}	9.01±0.37^{c}	6.91±0.18^{B}
C20:5n-3	1.84±0.03^{a}	1.88±0.06^{B}	1.99±0.04^{b}	1.54±0.04^{A}	2.03±0.09^{b}	2.00±0.09^{C}	1.90±0.07^{a}	2.16±0.10^{C}
C22:5n-3	0.79±0.04	0.84±0.04	0.91±0.02	0.73±0.01	1.09±0.02	0.95±0.04	0.86±0.01	0.57±0.02
C22:6n-3	1.15±0.10	1.22±0.02	1.20±0.04	1.03±0.03	1.63±0.07	1.61±0.05	1.10±0.03	0.84±0.02
SFA	40.45±0.20^{a}	41.72±0.25^{A}	39.89±0.14^{b}	40.34±0.32^{C}	39.73±0.44^{b}	39.70±0.14^{D}	39.50±0.18^{b}	41.04±0.28^{B}
UFA	59.55±0.17^{a}	58.28±0.67^{A}	60.11±0.23^{b}	59.66±0.53^{B}	60.27±0.14^{b}	60.30±0.14^{B}	60.50±0.12^{b}	58.96±0.12^{A}
MUFA	21.50±0.20^{a}	20.68±0.24^{A}	20.67±0.12^{b}	20.91±0.32^{A}	19.92±0.05^{c}	18.32±0.14^{B}	20.86±0.11^{b}	20.51±0.39^{A}
PUFA	38.06±0.18^{a}	37.59±0.39^{A}	39.44±0.26^{b}	38.76±0.56^{B}	40.35±0.39^{c}	41.99±0.28^{C}	39.64±0.22^{b}	38.45±0.43^{AB}
P/S	0.94±0.01^{a}	0.90±0.02^{A}	0.99±0.02^{b}	0.96±0.02^{B}	1.02±0.02^{b}	1.06±0.04^{C}	0.99±0.01^{b}	0.94±0.03^{AB}
n-6/n-3	6.54±0.15^{a}	5.89±0.11^{A}	6.52±0.09^{a}	6.94±0.09^{B}	5.55±0.02^{b}	5.91±0.10^{A}	5.83±0.07^{c}	6.97±0.14^{B}

The intramuscular fatty acid compositions are shown in Table 2. The pattern of FAs in the diet was pointed out that the saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) were the main fatty acids while monounsaturated fatty acids (MUFA) were less presented. The higher percentages were for palmitic acid (PA, C16:0), oleic acid (OA, C18:1n-9) and linoleic acid (LA, C18:2n-6). Similar experimental results have been found in Hernandez (2008) and Ramirez (2005). PA ranged from 26.98 to 28.28, OA ranged from 16.47 to 19.18 while LA ranged from 23.83 to 26.05 of total FA, respectively. From a nutritional point of view, the high unsaturated lipid profile makes meat interesting for following healthy lifestyle (Dalle Zotte et al., 2011). The proportion of total saturated fatty acids was lower (p<0.05) in the citrus pulp groups as compared to the control samples. In particular, PA decreased (p<0.05) in citrus pulp meats. Meat from the citrus pulp treatment showed a higher (p<0.05) total PUFA content as compared to control meats, relating to a higher percentage of C20:4n-6 ($p<0.05$), giving rise to a lower saturated/unsaturated ratio. Lanza (2004) reported an increasing level of polyunsaturation of intramuscular fatty acids in the meat from ostrich fed a citrus pulp based-diet.

CONCLUSION

In this study, the use of citrus pulp in rabbit diets had no significantly reduced the meat quality. Moreover, the proportion of total polyunsaturated fatty acids was higher in the citrus pulp groups as compared to the control samples. The finding is beneficial as reducing saturated fatty acids intake reduces the risk of coronary disease. Overall, citrus pulp can be used in growing rabbits and citrus 14% group tend to be higher polyunsaturated fatty acids. It should be encouraged not only in order to reduce feeding costs but also enhanced nutritional value. However, further research will be necessary to clarify the absorption and metabolism of citrus pulp bioactive components.

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