B-1074
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Indian J. Anim. Res.,
Print ISSN:0367-6722 / Online ISSN:0976-0555

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com

Nutritive value and meat characteristics of sheep fed *Toona sinensis* (A. Juss.)

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Received: 11-12-2018 Accepted: 29-06-2019 DOI: 10.18805/ijar.B-1074

ABSTRACT

Toona sinensis is a widely distributed tree in Asia with buds that are treasured as "forest-vegetables", while millions of mature leaves are discarded as waste. This study first analyzed the nutrient composition of mature leaves of *T. sinensis* and then explored their effects when fed to sheep. Results indicated that mature leaves of *T. sinensis* were rich in crude protein and minerals, and were readily eaten by sheep. Compared with grass-fed sheep (CK), the meat of *T. sinensis*-fed sheep (TS) had slightly higher content of protein, unsaturated fatty acid, essential amino acid, and lower cholesterol content. The score of the ratio coefficient of amino acids of meat from TS (81.01) was over 16% higher than CK (69.56). All results showed that the mature leaves of *T. sinensis* have positive effects on meat characteristics and nutritional status of sheep, and are promising as a novel, nutritious feed resource.

Key words: Feed, Mature leaves, Meat, Nutrition, Resource, Sheep, *Toona sinensis*.

INTRODUCTION

Food consumption is changing along with more rapid global industrialization and urbanization as well as the increasing population. Global meat production is projected to rise from 233 (in 2000) to 300 million tons (in 2020), milk production will go from 568 to 700 million tons, and egg production is projected to increase by 30% (Speedy, 2016). Since arable land is limited, more attention has recently been focused on exploiting woody trees and shrubs that can grow in marginal land and be used as ruminant feeds (Musco *et al.*, 2016). Some studies have characterized the nutrient value of locally available woody-feed resources, such as *Leucaena leucocephala*, *Moringa oleifera*, and *Prosopis juliflora* (Kumar *et al.*, 2015; Musco *et al.*, 2016; Ramirez-Lozano *et al.*, 2018). However, their feeding effects on meat quality remain, to a wide extent, unclear.

Toona sinensis (A. Juss.) Roem is a fast-growing tree in the family Meliaceae genus *Toona*, which is widely distributed in southeastern Asia, including India, Indonesia, Bhutan, Laos, Malaysia, Myanmar, Nepal, Thailand and especially south China (Peng *et al.*, 2008). Traditionally, the nutritious young buds of *T. sinensis* with their unique tangy flavor have been considered special "forest vegetables". In addition to their distinctive taste, the buds of *T. sinensis* are rich in polyphenols and possess many health benefits, such as antioxidative capacity and anti-inflammatory properties (Peng *et al.*, 2019). Mature leaves of *T. sinensis* contain a higher proportion of polyphenols and possess better antioxidative capacity than young leaves (Gong *et al.*, 2012; Liu *et al.*, 2014). However, the millions of tons of mature leaves of *T. sinensis* are wasted at present due to the lack of tangy flavor present in young leaves. Hence, the present study analyzed the feed value of the mature leaves of *T. sinensis* and evaluated feeding effects on meat characteristics and nutritional status of sheep.

MATERIALS AND METHODS

Plant materials: The mature leaves of *T. sinensis* were hand harvested on July 20th from the Golden Sun farm (Beijing, China). A small part were kept in a dry plastic foam box and taken to the lab for nutritional analysis; the remaining leaves were truncated, evenly mixed and vacuum-packed for subsequent feeding experiments.

Feeding of sheep: Twelve healthy male sheep (crossbred White Suffolk with local small-tailed Han-sheep), about 3 months old, were selected from Gold Sun farm (Beijing, China). Equal numbers of sheep were randomly allotted into the *T. sinensis*-fed group (TS) and the grass-fed group (CK). Sheep in TS were fed mature leaves of *T. sinensis*, and CK sheep were fed grass harvested from the farm to match normal grazing. All sheep were kept under confinement with uniform management conditions and offered 1.5 kg of their respective feed daily at 08:00 and 17:00 with free access to water. The feeding trial was conducted for 90 days. After being deprived of feed overnight (16 h), sheep were slaughtered according to the research of Werdi Pratiwi *et al.* (2007). Meats of hind legs of 3 randomly selected sheep from TS and CK were respectively collected and kept under -80°C for the nutritional analysis.

Analytical measurements: The crude protein, crude fat, and water content were analyzed according to AOAC (2005). Neutral and acid detergent fiber contents were determined according to Goering and Van Soest (1970). Amino acids and fatty acid profiles were evaluated according to the

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National Industry Standards of China GB/T 5009.124 (2003) and GB/T 22223 (2008). Mineral content was detected by 7700x inductively coupled plasma mass spectrometry (Agilent, USA). All chemicals used were analytical grade and obtained from Beijing Chemical Works (Beijing, China). All samples were analyzed in triplicate and the mean values were recorded.

WHO/FAO essential amino acid (EAA) pattern analysis (Yan and Jin, 2016) was employed for comprehensive nutritional assessment. The ratio of amino acid (RAA), ratio coefficient of amino acid (RC), and score of the RC (SRC) of meat samples were calculated according to the ideal protein pattern provided by the WHO/FAO as below:

RAAs = (EAAs content in sample/EAA in WHO/FAO ideal protein pattern) × 100%

RCs = RAAs of EAAs in sample/mean value of RAAs)

SRCs = (100 - variable coefficient of RCs × 100)

Statistical analysis: Descriptive statistical analysis and one-way ANOVA were conducted in IBM SPSS software package version 20.0.

Nutrient value of mature leaves of *T. sinensis*: Nutrient composition of young and mature leaves of *T. sinensis* was comparable (Table 1). Both were rich in crude protein, minerals, and amino acids. Mature leaves of *T. sinensis* had higher crude protein than grains such as maize (9.51%), wheat (11.71%) and barley (10.18%); and agro-industrial by-products, such as wheat bran (14.46%), rice polish (12.80%) and wheat straw (3.39%) (Kumar *et al*., 2015); and were comparable to the legumes *Clitoria ternate* (18.38%), *Dolichos lablab* (18.39%), and *Macroptilium bracteatum* (18.89%) (Hartutik *et al*., 2012).

The ratios of total essential amino acid content (TEAA) and total amino acids (TAA), and of TEAA and total non-essential amino acid content (TNEAA) of mature leaves of *T. sinensis* were 37.19% and 59.21%, respectively. These values were respectively close to the WHO/FAO recommended 40% and 60%, and were higher than those of young leaves (35.44% and 54.89%, respectively). High levels of delicious amino acids (DAA, including Glu and Asp) and sweet amino acids (SAA, including Ala, Gly, Ser, Pro, Thr, and Trp) in food could contribute to the desirable flavor. The ratios of DAA/TAA and SAA/TAA were 34.43%, 32.37% and 38.64%, 29.98% in mature leaves and young leaves, respectively.

Table 1: Composition and content of nutrients in the mature (ML) and young leaves (YL) of *T. sinensis*.

Nutrient	ML	YL	Nutrient	ML	YL
General component (%):			**Amino acid (%):**		
Water content	72.16	77.79	Lysine (Lys)**	1.05	1.23
Crude protein	19.49	21.72	Valine (Val)**	0.75	0.80
Neutral detergent fiber	31.87	24.33	Methionine (Met)**	0.14	0.18
Acid detergent fiber	15.68	13.63	Leucine (Leu)**	1.13	1.22
Crude fat	3.09	3.51	Threonine (Thr)**	0.66	0.69
Mineral (mg/kg):			Isoleucine (Ile)**	0.62	0.68
K (g/kg)	14.38	20.21	Phenylalanine (Phe)**	0.79	0.76
Ca (g/kg)	10.37	5.70	Tyrosine (Tyr)*	0.48	0.52
P (g/kg)	2.71	3.76	Cysteine (Cys)*	0.07	0.06
Mg (g/kg)	2.11	1.80	Glutamic (Glu)	3.80	5.28
Fe	107.83	78.99	Histidine (His)	0.33	0.35
Sr	57.48	28.80	Arginine (Arg)	0.75	0.87
Mn	21.73	13.89	Glycine (Gly)	0.74	0.79
Ba	20.82	12.16	Alanine (Ala)	1.00	0.93
Zn	19.12	27.40	Proline (Pro)	0.82	0.68
Na	12.84	18.08	Serine (Ser)	0.69	0.87
Cu	9.08	10.05	Aspartic (Asp)	1.47	1.41
Ni	0.63	0.83	TAA	15.30	17.31
Mo	0.14	0.21	TEAA	5.69	6.13
Se	0.08	0.09	DAA	5.27	6.69
Co	0.07	0.12	SAA	4.97	5.19
Cr (≤ 10.00) [a]	2.31	1.43	TEAA/TAA (%)	37.19	35.44
Pb (≤ 5.00) [a]	0.38	0.21	TEAA/TNEAA (%)	59.21	54.89
As (≤ 2.00) [a]	0.07	0.08	DAA/TAA (%)	34.43	38.64
Cd (≤ 0.50) [a]	0.09	0.10	SAA/TAA (%)	32.47	29.98

a. The maximum allowances of mineral substance in commercial feedstuffs based on the national health standards of China.**: essential amino acid; *: semi-essential amino acid; TAA: total amino acids content; TEAA: total essential amino acids content; TNEAA: total non-essential amino acids content; DAA: delicious amino acids; SAA: sweet amino acids.

Ca, Mg, Fe and Mn of mature leaves of *T. sinensis* were higher than in young leaves. Essential minerals for animals, such as Zn, Se, Mo and Co (Sethy *et al*., 2018; Talukdar *et al*., 2016) were also detected in mature leaves. The contents of Cr, Pb, As and Cd of mature leaves of *T. sinensis* were much lower than the allowances.

Effects of *T. sinensis* on meat characteristics of sheep: All sheep grew normally without any gastro-intestinal incidences or anorexia. As reported by Goff and Klee (2006), taste, smell, and related sensory perception of feedstuff are important for acceptance and palatability to livestock. During the feeding trial, sheep preferred *T. sinensis* over grass and the unique flavor of *T. sinensis* may be the reason.

Results of nutritional analysis of meats are shown in Table 2. General nutrient composition of meats from TS and CK were comparable. TAA (17.34%), TEAA (8.04%),

Table 2: Comparison of nutrients in the meats of sheep fed with mature leaves of *T. sinensis* (TS) and grass (CK).

Nutrient content	TS	CK	Nutrient content	TS	CK
General component:			**Amino acid (g/100 g):**		
Water (%)	73.90	74.50	Lysine (Lys)**	1.57	1.42
Ash (%)	1.00	1.00	Valine (Val)**	0.86	0.78
Crud protein (%)	19.50	18.80	Methionine (Met)**	0.49	0.45
Crud fatty (%)	5.40	4.90	Leucine (Leu)**	1.48	1.35
Carbohydrate (%)	0.20	0.80	Threonine (Thr)**	0.82	0.75
Energy (KJ/100g)	535.00	515.00	Tryptophan (Trp)**	0.18	0.12
Cholesterol (mg/100g)	55.00	56.20	Isoleucine (Ile)**	0.78	0.71
			Phenylalanine (Phe)**	0.93	0.95
Fatty acid (g/100 g)			Tyrosine (Tyr)*	0.67	0.95
Capric acid	0.01	0.01	Cysteine (Cys)*	0.26	0.27
Lauric acid	0.01	0.01	Glutamic (Glu)	2.94	2.72
Myristic acid	0.16	0.15	Histidine (His)	0.54	0.53
Myristoleic acid	0.01	0.03	Arginine (Arg)	1.10	1.01
Pentadecylic acid	0.03	1.00	Glycine (Gly)	0.77	0.69
Palmitic acid	1.08	-	Alanine (Ala)	0.99	0.90
Palmitoleic acid	0.07	0.07	Proline (Pro)	0.61	0.56
Margaric acid	0.07	0.06	Serine (Ser)	0.68	0.62
Cis-10- Heptadecenoic acid	0.03	0.02	Aspartic (Asp)	1.66	1.49
Stearic acid	0.82	0.82	TAA	17.34	16.27
Oleic acid	1.60	1.48	TEAA	8.04	7.76
Linoleic acid	0.18	0.14	DAA	4.60	4.21
Arachidic acid	0.01	0.01	DAA/TAA	26.51	25.87
α-Linolenic acid	0.03	0.02	SAA	5.45	4.93
HeneiCosanoic acid	0.02	0.03	SAA/TAA	31.43	30.32
Behenic acid	0.02	0.01	**Mineral (mg/kg)**		
Arachidonic acid	0.10	0.07	Fe	14.3	11.70
EPA	0.01	0.01	Zn	19.00	17.00
Total content	4.36	4.06	Ca	34.0	38.3

-: undetected; EPA: all *cis*-5,8,11,14,17-eicosapentaenoic acid; TAA: total amino acids content; TEAA: total essential amino acids content; DAA: delicious amino acids; SAA: sweet amino acids.

Table 3: Essential amino acid scores of the meats of sheep fed with mature leaves of *T. sinensis* (TS) and grass (CK).

Amino acid	WHO/FAO Mode (mg/g pro)[a]	TS Mode (mg/g pro)	CK Mode (mg/g pro)	RAA		RC		SRC	
				TS	CK	TS	CK	TS	CK
Threonine	40	42	40	105.26	99.34	0.95	0.92	81.01	69.56
Valine	50	44	41	88.31	82.66	0.80	0.77		
Tryptophan	10	9	6	89.74	63.83	0.81	0.59		
Lysine	55	81	76	146.57	137.62	1.33	1.28		
Methionine +Cysteine	35	38	38	109.60	109.57	0.99	1.02		
Phenylalanine +Tyrosine	60	82	101	137.18	169.06	1.24	1.57		
Leucine	70	76	72	108.42	102.58	0.98	0.96		
Isoleucine	40	40	38	99.62	94.55	0.90	0.88		

a. Data are from Lan *et al*., 2010; pro: protein; RAA: ratio of amino acid; RC: ratio coefficient of amino acid; SRC: score of RC.

DAA (4.60%), SAA (5.45%), DAA/TAA (26.51%), and SAA/TAA (31.43%), which may contribute to desirable flavor in the meat of TS group, were higher than control. Meats from TS and CK groups had comparable total fatty acids content, but the content of unsaturated fatty acids and essential fatty acid of meats from TS were slightly higher than CK. Moreover, the meats of the TS group had more Fe (14.30 mg/kg) and Zn (19.00 mg/kg) than CK.

Nutritional status assessment for meats of *T. sinensis*-fed sheep: In WHO/FAO essential amino acid pattern analysis, the closer RAAs were to 100 and RCs to 1, meant that the amino acids in food were much closer to the required protein pattern for adults. In addition, the closer SRCs were to 100, the higher nutritional value the food presents. As shown in Table 3, SRC for meats of the TS group was 81.01, which was 16% higher than CK (69.56). Thus, meats of the TS group were nutritionally superior over meats of CK.

CONCLUSION

Results of the present study indicated that mature leaves of *T. sinensis* were rich in crude protein, essential amino acids, and minerals, and have positive effect on meat characteristics and nutritional status of sheep. Thus, exploring mature leaves of *T. sinensis* as a novel feedstuff could reduce waste of this resource and potentially help to mitigate the global feed shortage.

ACKNOWLEDGEMENT

This study was financially supported by the Central Public-interest Scientific Institution Basal Research Funds (CAFYBB2017QA004) and the Southeast Guizhou Forestry Research Funds (C078).

REFERENCES

AOAC. (2005). Official Methods of Analysis of AOAC International. 18th Edition. Association of Official Analytical Chemist. Washington, DC, USA.

GB/T 22223. (2008). Determination of total fat, saturated fat, and unsaturated fat in food-hydrolytic extraction-gas chromatography. Standardization administration of the People's Republic of China. Beijing, China.

GB/T 5009.124. (2003). Determination of amino acids in foods. Standardization administration of the People's Republic of China. Beijing, China.

Goering, H.K. and Van Soest, P.J. (1970). Forage fiber analysis (apparatus, reagents, procedures, and some application). In Agricultural handbook, No. 379. Agricultural Research Services, USDA: Washington D.C.

Goff, S.A. and Klee, H.J. (2006). Plant volatile compounds: sensory cues for health and nutritional value? *Science*. **311**: 815-819.

Gong, G.L., Chen, S., Zeng, Q., Li, N., Yang, W.J. (2012). Study of extraction process of polyphenol from old leaves of *Toona sinensis*. *Advanced Science Letters*. **13**: 867-871.

Hartutik, S., Fernandez, P., Ratnawaty, S. (2012). Evaluation of legume herbs nutritive value as a ruminant feed and nitrogen supply on soil in West Timor, Indonesia. *Pakistan Journal of Agricultrual Research*. **25**(4): 323-331.

Kumar, D., Datt, C., Das, L.K., Kundu, S.S. (2015). Evaluation of various feedstuffs of ruminants in terms of chemical composition and metabolisable energy content. *Veterinary World*. **8**(5): 605-609.

Liu, C.J., Zhao, Y.L., Li, X.J., Jia, J.Y., Chen, Y.Y., Hua, Z.T. (2014). Antioxidant capacities and main reducing substance contents in 110 fruits and vegetables eaten in China. *Food and Nutrition Sciences*. **5**(4): 293-307.

Musco, N., Koura, I.B., Tudisco, R., Awadjihe, G., Adjolohoun, S., Cutrignelli, M.I., Mollica, M.P., *et al*., (2016). Nutritional characteristics of forage grown in south of Benin. *Asian-Australasian Journal of Animal Sciences*. **29**(1): 51-61.

Peng, H., Mabberley, D.J., Pannell, C.M., Edmonds, J., Bartholomew, B. (2008). *Meliaceae*. In: Flora of China. [Wu, Z.Y., Raven, P.H. and Hong, D.Y. (eds.)], Science Press and Middouri Botanical Garden Press, Beijing and St. Louis. pp. 111-131.

Peng, W., Liu, Y., Hu, M., Zhang, M., Yang, J., Liang, F., Huang, Q., Wu., C. (2019). *Toona sinensis*: a comprehensive review on its traditional usages, phytochemisty, pharmacolocy and toxicology. *Revista Brasileira de Farmacognosia*. **29**(1): 111-124.

Ramirez-Lozano, R.G., Gonzalez-Rodriguez, H., Ledezma-Torres, R.A. (2018). Nutritional evaluation of *Senegalia greggii* and *Prosopis juliflora* as browse supplements for sheep. *Indian Journal of Animal Research*. **52**(9): 1304-1308.

Sethy, K., Behera, K., Mishra, S.K., Gupta, S.K., Sahoo, N., Parhi, S.S., Mahapatra, M.R., Khadanga, S. (2018). Effect of organic zinc supplementation on growth, metabolic profile and antioxidant status of Ganjam sheep. *Indian Journal of Animal Research*. **52**(6): 839-842.

Speedy, A.W. (2016). Overview of world feed protein needs and supply. http://www.fao.org/docrep/007/y5019e/y5019e05.htm.

Talukdar, D.J., Talukdar, P., Ahmed, K. (2016). Minerals and its impact on fertility of livestock: A review. *Agricultural Reviews*. **37**(4): 333-337.

Werdi Pratiwi, N.M., Murray, P.J., Taylor, D.G. (2007) Feral goats in Australia: a study on the quality and natritive value of their meat. *Meat Science*. **75**: 168-177.

Yan, Z. and Jin, Y. (2016). Quality evaluation of tibetan mutton based on amino acid and fatty acid. *Science and Technology of Food Industry*. **37**(3): 351-354, 363.