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**THE EFFECTS OF CONDENSED TANNINS UPON NUTRIENT  
DIGESTION AND METABOLISM AND UPON ANIMAL  
PRODUCTION IN SHEEP FED *LOTUS CORNICULATUS***

**Yuxi Wang**

**1995**

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PRODUCTION IN SHEEP FED *LOTUS CORNICULATUS***

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**Yuxi Wang**

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## ABSTRACT

(Yuxi Wang, Department of Animal Science, Massey University, Palmerston North, NEW ZEALAND. *The effects of condensed tannins upon nutrient digestion and metabolism and upon animal production in sheep fed Lotus corniculatus*)

A series of indoor metabolism and grazing experiments were conducted at AgResearch Grasslands and Massey University, Palmerston North, New Zealand, to study the effects of condensed tannins (CT) in *Lotus corniculatus* (birdsfoot trefoil; cv. Grasslands Goldie) upon nutrient digestion and metabolism and upon animal production using sheep as the experimental animal. Half of the animals in each experiment were supplemented with polyethylene glycol (PEG; MW 3500). PEG specifically binds and inactivates CT without affecting other nutrients and is indigestible; hence effects of CT were specifically defined by comparing control sheep (CT acting) with PEG supplemented sheep (CT inactivated). A rotational grazing system with some restriction in feed allowance was used in most of the grazing experiments. For the indoor experiments, sheep were held in metabolism crates and fed fresh *L. corniculatus* from overhead belt feeders at hourly intervals.

1. The effects of CT in *L. corniculatus* (35 g total CT/kg DM) upon nutrient digestion and upon metabolism of methionine, cystine and inorganic sulphate in plasma were determined. PEG was continuously infused into the rumen of half the sheep. Principal measurements in the two groups were plasma irreversible loss rate (IRL) and interconversions of methionine, cystine and inorganic sulphate using <sup>35</sup>S labelling. Action of CT considerably reduced the concentration of ammonia and molar proportions of *iso*-butyric acid, *iso*-valeric acid and *n*-valeric acid in rumen fluid, but had no effects upon total volatile fatty acid (VFA) concentration and molar proportions of major VFAs. CT greatly increased the IRL of plasma cystine (13.1 vs 7.0 μmol/min) and reduced IRL of plasma inorganic sulphate (36.8 vs 48.1 μmol/min) but had no effect upon methionine IRL. Action of CT increased transulphuration of methionine to cystine (4.37 vs 1.24 μmol/min) and increased cystine flux to body synthetic reactions (11.89 vs 5.41 μmol/min). CT had no effect upon the proportion of methionine total flux transferred to sulphate (0.05 vs 0.06; i.e. oxidation) but markedly reduced the proportion of cystine flux transferred to sulphate (0.09 vs 0.27). CT had no effect upon the apparent digestion of cellulose and minerals, slightly depressed DM, OM and hemicellulose apparent digestion and markedly reduced the apparent digestion of nitrogen (N). Action of CT also reduced protozoa numbers in rumen fluid.

2. The productivity of lactating ewes (Exp 1) and weaned lambs (Exp 2) grazing swards of *L. corniculatus*, lucerne (*Medicago sativa*; cv. Grasslands Oranga) and a mixture of lucerne and lotus were compared in two grazing experiments in the 1991/1992 summer. Total CT content was 32-57 g/kg DM for lotus, 8-10 g/kg DM for the mixture and was negligible for lucerne (< 2 g/kg DM). In Experiment 1, ewe wool production and lamb live weight gain (LWG) did not differ between forages, but ewe LWG was greater on lotus than on lucerne (251 vs 65 g/d), with the mixture being intermediate (115 g/d). In Experiment 2, voluntary feed intake (VFI; 1.76 vs 1.65 kg OM/d), LWG (228 vs 183 g/d), wool production (2.78 vs 2.25 kg) and carcass weight (20.4 vs 17.8 kg) were greater for lambs grazing lotus than lucerne; lambs grazing the mixture had similar VFI (1.63 kg OM/d) to those grazing lucerne, but wool production (2.49 kg) was intermediate between lucerne and lotus lambs. Lotus did not affect carcass fatness (GR 13.1 vs 12.8 mm). It was concluded that *L. corniculatus* supported high levels of sheep productivity, with the results suggesting that part of the response may be due to increased protein supply from action of CT in the digestive system.

3. A grazing experiment was conducted for 22 weeks in the 1992/93 summer to study the effects of CT upon lamb LWG, wool growth and rumen metabolism, and to compare the productivity of lambs grazing *L. corniculatus* and lucerne. PEG was given orally twice daily to half of the lambs grazing each sward. Lotus contained 34 g total CT/kg DM in the diet selected, whilst there was essentially no CT in lucerne. Compared to lambs grazing lucerne, lambs grazing lotus had slightly lower VFI, and higher LWG, carcass weight gain, carcass dressing-out percent and wool growth. PEG supplementation had no effect on these measurements or upon the composition of rumen fluid in lambs grazing lucerne. However, in lambs grazing lotus, PEG supplementation reduced wool growth (10.9 v. 12.1 g/day), slightly reduced LWG (188 v. 203 g/day), increased rumen ammonia concentration, and increased the molar proportions of *iso*-butyric, *iso*-valeric and *n*-valeric acids and protozoa numbers in rumen fluid. PEG supplementation did not affect carcass gain, carcass fatness or the molar proportion of rumen acetic, propionic or *n*-butyric acids in lambs grazing lotus.

4. The effects of CT in *L. corniculatus* upon the lactation performance of ewes rearing twin lambs was measured in an 8 week grazing experiment in the spring/summer of 1993. Half of the ewes were supplemented orally twice daily with PEG. Lotus contained

45 g total CT/kg DM in the diet selected, with an *in vitro* digestibility of 73%. The results showed that action of CT slowed down the decline in milk production and secretion rates of protein and lactose after the attainment of peak lactation, resulting in more milk (21%), more milk protein (14%) and more milk lactose (12%) secretion in mid and late lactation compared to CT inactivated ewes. CT reduced milk fat percentage but not fat secretion rate. CT had no effect upon VFI, LWG and wool growth of lactating ewes rearing twin lambs. Plasma urea and glucose concentrations were reduced due to action of CT. CT had no effect upon concentrations of non-esterified fatty acids (NEFA), growth hormone and insulin in the plasma, had no effect upon molar proportions of acetic, propionic and *n*-butyric acids in rumen fluid, but markedly reduced concentrations of ammonia and molar proportions of *iso*-butyric, *iso*- and *n*-valeric acids in rumen fluid.

5. The effect of CT upon the true and apparent digestion of methionine and cysteine in the small intestine (SI) of sheep fed *L. corniculatus* containing 30 g total CT/kg DM were determined, using sheep prepared with rumen and abomasal cannulae. An indigestible liquid phase marker chromium ethylene diamine tetra acetic acid (Cr-EDTA) was continuously infused into the rumen of all sheep, and PEG was continuous infused into the rumen of half the sheep. The true digestibility of methionine and cysteine in the SI and their absorption sites in the SI were measured from continuous intra-abomasal infusion of plant homogenate from *L. corniculatus* containing <sup>35</sup>S-labelled protein. Action of CT substantially reduced the true digestibility of methionine (0.72 v 0.88) and cysteine (0.66 v 0.81) in the SI, but increased the total amount of plant methionine and cysteine absorbed in the SI due to reduced rumen degradation. Action of CT slowed the digestion of both <sup>35</sup>S-methionine and <sup>35</sup>S-cysteine in the SI, and increased the flux of both amino acids in the mid and latter thirds of the SI. CT increased abomasal flux (as a proportion of eaten) of total methionine (0.88 v 0.76) and total cysteine (0.74 v 0.62), and increased absorption of total methionine (0.72 v 0.63 g/g eaten) but not total cysteine (0.49 v 0.48 g/g eaten) from the SI. Calculated endogenous loss of cysteine at the terminal ileum was greater than for methionine and both appeared to be increased by action of CT.

It was concluded that action of CT in *L. corniculatus* increased wool growth rate in high wool producing sheep and increased milk production in lactating ewes without affecting VFI, thus improving production efficiency. It was deduced that the improved animal production was probably due to the action of CT reducing rumen protein degradation,

increasing non-ammonia nitrogen (NAN) flux into the SI, increasing essential amino acid (EAA) especially methionine absorption from the SI, and increasing the flux of cystine to body synthetic reactions. Further researches are needed to study the effects of CT in the range 10-20 g/kg DM on animal production and nutrient metabolism, and to study the effects of forage CT upon milk production and composition in dairy cows.

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## LIST OF ABBREVIATIONS

AA	amino acids
ADF	acid detergent fibre
A-V	arterio-venous
BCT	bound condensed tannins
BF	blood flow
BSA	bovine serum albumin
BW	body weight
CA	metabolite concentrations in arterial blood
cm	centimetre
CP	crude protein
Cr	chromium
Cr-EDTA	chromium ethylenediaminetetra acetic acid
CT	condensed tannin
CV	metabolite concentrations in venous blood
CYS	cystine
CW	carcass weight
D	digestibility
d	day
DM	dry matter
DMI	dry matter intake
DNA	deoxyribonucleic acid
DP	degradable protein
DPM	disintegrate per minute
EAA	essential amino acids
ECT	extractable condensed tannins
Exp	experiment
FCT	fibre bound condensed tannins
F	faecal OM output
FE	faecal energy

FG	fermentation gas energy
Fig	figure
FO	faeces output
FrCT	free condensed tannins
FV	feeding value
g	gram
GE	gross energy
GI	gastro-intestine
GR	a measurement of total soft tissue depth over the 12th rib at a point 11 cm from the carcass midline
h	hours
ha	hectare
H-	hydrogen
HCl	hydrochloric acid
HPLC	high performance liquid chromatography
HT	hydrolysable tannins
ID (i.d.)	internal diameter
INAN	increment of NAN flux into the SI
IRL	irreversible loss rate
iu	international units
kBq	kilo-becquerel
kg	kilograms
$K_f$	efficiency of utilization of ME for fattening
$K_g$	efficiency of utilization of ME for growth
$K_l$	efficiency of utilization of ME for lactation
$K_m$	efficiency of utilization of ME for maintenance
l	litres
LO	lotus
Ltd	limited
LU	lucerne

LWG	liveweight gain
m	metres
mBq	mega-becquerel
ME	metabolisable energy
MET	methionine
meq	milliequivalent
mg	milligram
min	minute
MJ	megajoule
ml	millilitres
mm	millimetres
mmol	millimole
mol	mole
MW	molecular weight
N	nitrogen
Na	sodium
NAN	non-ammonia nitrogen
NaOH	sodium hydroxide
nd (ND)	no determined
NDF	neutral detergent fibre
NEAA	non-essential amino acid
NH <sub>3</sub>	ammonia
NV	nutritive value
NZ	New Zealand
OM	organic matter
OMD	organic matter digestibility
OMI	organic matter intake
OPA	orthophthaldehyde
PC	cyanidin
PCSII	Phase Combining System II
PCT	protein bound condensed tannins
PD	Delphinidin
PEG	polyethylene glycol
PITC	pyenyliothiocyanate

P+M	productive processes and maintenance
PRPs	proline-rich proteins
Pty	Company
PVP	Polyvinylpyrrolidone
RCEL	rumen digestion as proportion of total digestion of cellulose
RFC	readily fermentable carbohydrate
RHCEL	rumen digestion as proportion of total digestion of hemicellulose
$^{103}\text{Ru-P}$	$^{103}\text{Ru}$ -labelled tris-(1,10-phenanthroline)-ruthenium II chloride
rpm	revolutions per minute
S	sulphur
$^{35}\text{S}$	radioactive isotope of sulphur
SA	specific activity
SAA	sulphur amino acids
SE	standard error
SEM	standard error of mean
SI	small intestine
t	tonne
TCA	trichloroacetic acid
TCT	total condensed tannin
TQ	transfer quotient
UK	United Kingdom
UDP	undegraded protein
UE	urine energy
$\mu\text{l}$	microlitre
$\mu\text{mol}$	micromole
USA	United States of America
VFA	volatile fatty acids
VFI	voluntary feed intake
v/v	volume by volume
WGR	wool growth rate
WSC	water soluble carbohydrates

w/v

weight by volume