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HEAT TREATMENT OF CANOLA MEAL AND SUBSEQUENT AVAILABILITY OF RUMEN ESCAPE PROTEIN AND AMINO ACIDS IN RUMINANTS

A Thesis

Submitted to the Faculty

of

Graduate Studies

The University of Manitoba

by

Tobias Atali Onyango

In Partial Fulfilment of the

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of

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Department of Animal Science

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TOBIAS ATALI ONYANGO

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

As a continuing effort to increase the level of rumen escape protein and post ruminally available amino acids (AA) in high producing ruminants of today such as dairy cows in early lactation, three trials were conducted using three non-lactating Holstein cows fitted with rumen and T-shape proximal duodenal canulae; fifty adults Single Comb White Leghorn cockerels; and thirty two lactating cows. The purpose was to determine the effect of moist heat treatment of canola meal (CM) as a source of rumen escape protein as measured from *in situ* rumen and lower gastro intestinal (GI) tract degradability of: dry matter (DM), fiber, protein, essential (EAA) and non essential (NEAA); availability of EAA, NEAA and true nitrogen-corrected metabolizable energy (TME_n) in precision-fed cockerels; and feed intake, milk production, milk composition and body weight change in dairy cows in early lactation. Four different batches of commercial CM were exposed to moist heating at 110°C for 0 (CM 0), 23 (CM 23), 45 (CM 45) and 60 (CM 60) min through a steam jacketed conveyor and slowly steeped at passage rates of 200, 110 and 90 kg h^{-1} respectively. A bypass protein supplement (Bi) made from a mixture of animal-vegetable products was formulated for comparison with CM 60, based on similar calculated rumen escape EAA.

Trial I was an *in situ* 3 X 3 Latin Square design using a sequence of rumen *in situ* bag incubations, *in vitro* pepsin-HCl incubations and lower GI tract mobile nylon bag technique. Two bag types, monofilament and multifilament were compared and effect of inclusion of similar or different test supplement in cows' diet was tested. Crude protein (CP) content of CM 60 and Bi were similar ($P>0.05$), but heat treatment increased

(P<0.05) neutral detergent fibre (NDF), acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitogen (NDIN) contents. Rumen degradation of protein from CM 0 was higher (P<0.05) than other levels of heat treated CM. Type of protein in cows' diet affected (P<0.05) rumen protein degradation and subsequent rumen disappearance of nitrogen. Protein and EAA degradation was higher (P<0.05) in monofilament bag type than multifilament type. Lower GI tract degradation of protein from both bag types was not affected (P<0.05) by removal of pepsin-HCl digestion step. Heat treatment did not (P<0.05) change individual EAA and NEAA but tended to decrease (P<0.05) concentration of arginine, leucine, lysine, methionine and valine. Disappearance of EAA 12 h post rumen incubation was reduced (P<0.05) in the rumen but increased (P<0.05) in the lower GI tract with 60 min heat treatment and resulted in increased (P<0.05) fecal excretion of, arginine, histidine, isoleucine, lysine, methionine and threonine. These changes resulted in an increased (P<0.05) 80-90% available EAA quantity in the small intestine.

Trial II was a randomized block design using five groups each of ten precision-fed cockerels. Test supplements were similar to those in Trial I. Heat treatment did not (P<0.05) change TME_n contents of CM but decreased (P<0.05) availability of EAA and NEAA [g (16g N)$^{-1}$] and as percent of meal fed. The Bi supplement was similar to CM 60 for EAA availability.

Trial III involved fourteen primiparous (PP) and eighteen multiparous (MP) Holstein cows two weeks post-partum arranged in a split-plot design for 12 lactation weeks. Heat treated CM 60 or Bi substituted CM 0 as Iso-nitrogenous and iso-caloric diets fed as total mixed ration once daily. Dry matter intake (DMI) of CM 0 and CM 60 was higher ($P<0.05$) than Bi. The Bi diet reduced ($P<0.05$) DMI compared with other CM diets but resulted in equal milk yield when averaged over all cows. Milk yield by PP cows was higher in CM 60 than CM 0 and lower ($P<0.05$) in Bi diet than CM 0 and CM 60. Parity affected ($P<0.05$) milk yield with MP cows producing 34% more milk d^{-1} than PP cows. Treatment and parity did not affect milk contents of fat, protein, SNF, body weight and condition score over the experimental time.

Results from these trials indicated decreased ($P<0.05$) rumen degradation of CM with increased heating, resulting in higher levels of protein and AA availability post-ruminally. Although the potential for rumen escape of heat treated CM increased $P<0.05$), milk yield and composition did not differ ($P<0.05$) from the unheated CM> It is suggested that higher temperatures above 110°C or longer heating times than 60 min be adopted with continued use of CM in dairy rations.

DEDICATION

To my wife, Grace and to our children, Arnold, Geraldine, Preston and Michael. Without their support, encouragement, understanding and patience I would not have accomplished this task as far away from home as it was. Their encouragement and that of my parents, Serefina and Naphtali, was indeed a constant source of inspiration to me throughout the time of this programme.

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FORWARD

This thesis is written in a manuscript format and three manuscripts will be submitted for publication. The authors for manuscript I will be T.A. Onyango, J.R. Ingalls and G.H. Crow. The authors for manuscript II and III will be T.A. Onyango and J.R. Ingalls.

The studies comprised in this thesis have resulted in the following publications/presentations:

1. Onyango, T.A. and Ingalls, J.R. 1994. Feed intake and lactation response of cows fed heat treated canola meal and high undegradable protein supplements in early lactation. J. Anim. Sci. 72:, suppl. 1 / J. Dairy Sci. 77:, suppl. 1
2. Onyango, T.A. and Ingalls, J.R. 1994. Heat treated canola meal as a source of rumen escape protein for dairy cows. Manitoba Agri-forum. pp 128.
3. Onyango, T.A., Ingalls, J.R. and Crow, G.H. 1995. Rumen and lower GI tract degradability of heated canola meal and effect of dietary protein, bag type and pepsin-HCl digestion on nitrogen and amino acid degradability. Can. J. Anim. Sci. (abstract).

ABBREVIATIONS USED IN THE TEXT

AA - Amino acid

ADF - Acid detergent fibre

ADIN - Acid detergent insoluble nitrogen

AME - Apparent metabolizable energy

ATP - Adenosine tri-Phospahte

Bi - By-pass protein supplement

CH_4 - Methane

CM - Canola meal

CO_2 - Carbon-dioxide

CP - Crude protein

CSM - Cotton seed meal

DM - Dry matter

DMI - Daily dry matter intake

DIP - Degradable intake protein

EAA - Essential amino acids

ED - Effective degradability

EDDM - Effective degradability of dry matter

EDN - Effective degradability of nitrogen

EDP - Effective degradability of protein

EE - Ether extract

EEL - Endogenous energy loss

GE - Gross energy

GIT - Gastro-intestinal tract

GLM - General linear models procedure of Statistcal Analysis System.

MP - Multiparous cows.

N - Nitrogen

NDF - Neutral detergent fibre

NDIN - Neutral detergent insoluble nitrogen

NEAA - Non-essential amino acids

NH_3 - Ammonia

NH_3N - Ammonia nitrogen

NPN - Non-protein nitrogen

PP - Primiparous cows.

RSM - Rapeseed meal

SBM - Soybean meal

SNF - Solids-not-fat

TME_n - True metabolizable energy (endogenous corrected)

TMR - Total mixed ration

UIP - Undegradable intake protein

Urea-N - Plasma urea nitrogen

VFA - Volatile fatty acids

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INTRODUCTION

The ability of ruminants to digest relatively unlignified plant cell wall materials in the rumen places them in a particular niche in the food chain. The capacity to digest cell wall carbohydrates results from microbial fermentation in the rumen. Justification for continued use of all ruminants for meat, milk, hide and wool or hair production resides in four broad areas: their ability to digest carbohydrate sources not digested by monogastric species; their ability to use non-protein nitrogen (NPN) to supply the host animal with protein through microbial growth in the rumen; their efficient utilization of dietary protein (provided it has an optimum balance of degradable and undegradable protein) and their highly efficient use of dietary lipids for productive purposes.

The digestive tract of ruminants provide an environment capable of supporting a dense population of microorganisms that ferment carbohydrates and other plant materials to produce mainly volatile fatty acids (VFA), methane (CH_4), carbon dioxide (CO_2) and energy (adenosine tri-phosphate, ATP) for the growth of microorgamisms. The rumen microorganisms on the other hand, have the ability to synthesize amino acids (AA) and proteins from ammonia, which provide the major source of protein for the host ruminant animal under regular circumstances, to be post-ruminally digested and finally available as AA through the use of proteolytic enzymes in the lower gastro-intestinal tract (GIT).

With continuing research efforts, debate has arisen as to the adequacy of microbial protein as the sole source of protein and AA for high producing ruminants of today; and more specifically, with high producing dairy cows in early lactation being one major area of focus and concern. It has been suggested from various studies that there is need to provide some form of *rumen bypass (escape) protein* also referred to as ruminally undegradable intake protein (UIP) to such classes of ruminants in order to provide sufficient levels of essential AA required for high levels of production.

Bypass protein has been defined as any portion of a protein meal which escapes the rumen intact and is presented for digestion in the lower GIT or that part of the protein which on escaping rumen fermentation is digested and absorbed from the small intestine. High requirements for UIP have led to substantial research efforts to improve feedstuff resistance to microbial degradation, naturally, or through chemical, physical and or heat treatment which may modify the protein with a purpose of increasing UIP levels available post-ruminally for high producing dairy cows.

Canola meal (CM) contains 38 to 46% crude protein (CP) with relatively low UIP (Kendall et al 1991; Boila and Ingalls 1992). Research has focused on increasing UIP in CM and its potential as a protein source in the rations of high producing cows. The utilization of CM in dairy cattle rations has received extensive investigation. The review of research results from 1968 to 1979 by Bell (1982) show that up to 346 studies were conducted on CM alone, as a protein source for animals. Other experiments have since shown the value of CM in dairy diets as the main protein source (Thomke et al. 1983)

These reports have shown that CM will either maintain or slightly increase milk yield compared to soybean meal (SBM) based rations. However, in the past 20 years milk production per cow has increased about 100% with some of the top herds producing 50% more than the average. These large increases in milk yield require new strategies to meet the cow's nutrient requirements and require research to apply these strategies to make efficient and economic use of the available feedstuffs such as CM.

Because of the cow's limited ability to consume feed and coupled with reliance on rumen bacteria to produce AA, an increase in energy and rumen escape of essential amino acids (EAA) is required particularly in early lactation and at peak milk production. Research work has shown that in some cases, increasing the amounts of rumen escape protein will increase milk yield and hence the need for high quality dietary protein supplementation for high producing cows (McKinnon et al. 1990).

The hypothesis for these studies was that untreated CM protein is rapidly degraded in the rumen as is barley and high protein legume forages which form the major part of dairy rations and do not meet NRC (1989) requirements for lactating dairy cows. Heat treatment of CM can improve the value of protein through increased amounts of rumen escape of essential AA available for assimilation and subsequent increased milk yield. Thus the value of canola meal as a source of AA for absorption in the gastro intestinal tract (GIT) could be improved by decreasing the amount of degradation of CM protein in the rumen.

Studies were conducted using CM exposed to moist heat treatment at different temperatures with the objectives of measuring the effect of moist heat treatment of CM on, (1) the rates of dry matter (DM), acid detergent fibre (ADF), neutral detergent fibre (NDF), nitrogen (N), and amino acids' disappearance from the rumen and lower GIT for CM. This was conducted as an *in situ* study using rumen and mobile nylon bags incubated in cannulated lactating dairy cows; (2) energy level and amino acid availability as assayed using precision fed roosters; (3) feed intake, milk production and milk