FERMENTED BLOODMEAL FOR GROWING PIGS

BY

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B. Sc. ANIMAL PRODUCTION (Honours)

THESIS

Submitted to the Graduate School, Egerton University in partial fulfillment of the requirements for the degree of Master of science in Animal Production (Animal Nutrition Option).

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1998

DECLARATION

THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY.

Signed------------------------ Date 9/9/98

This thesis has been submitted with our approval as university supervisors:

1. Signed------------------------ Date September 9th, 1998

   Dr. James K. Tuitoek.

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   Dr. Henry K. Muiruri.

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SUMMARY

Four experiments were set up to evaluate the suitability of fermented blood meal (FBM) in pig diets. Experiment one evaluated the effect of inoculation on rate of fermentation. Previously fermented blood meal was used as the inoculant replacing quantities of fresh blood-molasses mixture at levels of 10 to 90%. The experiment had 9 treatments with three replicates each arranged in a completely randomized design. Experiment two compared growth rates supported by diets containing wet or dry FBM. The experiment was a 2 x 2 factorial using 12 pigs with equal sex distribution. Experiment three assessed the utilization of FBM by pigs in a digestibility and nitrogen balance study. Four male castrates arranged in a 4 x 4 Latin square were used in the experiment. Experiment four sought to establish the optimum inclusion level of fermented dry blood meal (FDBM). Sixteen growing pigs blocked on sex and weights were used in the experiment in a completely randomized block design. There were four treatments each with 4 replicates.

In experiment one, all the treatments with inoculants had a faster rate of pH drop than the control. All the inoculated samples attained a pH of 4.2 in less than five days while the control took seven days. In experiment two using wet or dry FBM in pig rations did not affect average daily gain (ADG), or feed conversion ratio (FCR) but the diet with wet blood meal supported higher feed intake than the diet with dry blood meal. Females had a better FCR than the males. In experiment three, substituting soybean meal (SBM) on CP basis with 10% of either fermented wet bloodmeal (FWBM) or FDBM significantly reduced dry matter

(DM) digestibility of the diets but did not affect nitrogen (N) digestibility. Nitrogen retention (NR) and biological value (BV) were similar for the three test diets. N digestibility for FWBM and FDBM was also similar to N digestibility in SBM (44% CP). In experiment four, the rate and efficiency of gain for pigs receiving 5% and 11% FDBM were similar while FI was significantly reduced at 11% FDBM. Pigs receiving 7 and 9% FDBM ate more than the pigs receiving 5 or 11% FDBM. ADG and FCR were however similar for all the levels of substitution. Males in this experiment ate more and grew faster than the females but were similar in FCR.

Key words: Fermented Blood meal, Growing pigs, pH, Nitrogen retention, Digestibility.

ACKNOWLEDGMENT

I must thank, in particular, my supervisors Drs. J.K. Tuitoek and H.K. Muiruri for their thorough guidance, suggestions and assistance throughout this study. It is impossible to do justice to their inestimable professional contributions towards completion of this work.

Thanks must also be given to others who were kind enough to help in the process of making this study a success. In particular, I thank Dr. C. Njeru and Prof. D. Nassiuma of animal science and mathematics departments respectively, for their assistance in data analysis, Mr. Sang, the Tatton farm manager, for his contribution of experimental materials and space to conduct the experiments and finally Mr. J. Toroitich of the veterinary department attached to Mogotio slaughter house for his great assistance in collecting the necessary quantities of raw blood. The contribution of my fellow students, Mr. F. Kioko, Mr. W. Chemjor and Mr. Mukabwa, in terms of labour, encouragement and advice cannot also be overlooked.

Thanks to Egerton University for offering the scholarship without which this programme would not have been possible.

Finally, may I thank my teenage son Kimathi, who may have sacrificed most during the pursuit of this programme. I also warmly thank my parents for the moral and material support during the cause of this programme.

DEDICATION

To my son Kimathi, my parents and all who may need to use the information contained herein.

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CHAPTER ONE

INTRODUCTION

Pig production in Kenya has progressively shifted from large scale to small scale farms. In 1963 the share of the market controlled by small scale farmers was only 11% and by 1972 it had risen to about 50% (Tuitoek, 1984). Today the share of the pig market controlled by small scale farmers is about 90% (Livestock project appraisal report, 1992). This is expected especially with the massive subdivision of the former white owned lands amongst the Africans in the 1970's and 80's. By 1992 Kenya was reported to have 2.7 million small holders with 80% of them having less than two hectares of land (FAO, 1992). The increase in human population has also caused further reduction in land sizes. The small land sizes would promote enterprise shift to pigs. Other factors have however prevented this enterprise shift from occurring. It has been reported that high feed costs have caused a decline in pig production in Rift Valley Province (MOALD & M, 1994).

The small scale farmers mainly keep pigs alongside other animals in addition to crop farming. Some farmers keep pigs primarily to utilise the kitchen and farm wastes as well as earn some income when the need for money arises. Under these circumstances feeding standards are usually ignored. Tuitoek (1984) reported that in Western Kenya, pigs are fed when feed is available otherwise they are left to graze or forage is cut and brought to them. These pigs usually take long time in the farm before they are marketed. This consequently causes poor returns to the farmers. Those small scale farmers who have injected some bit of commercialism in the pig enterprise also shy away from recommended standards of feeding due to the high costs of feed and also the necessity to utilise the scarce resources for other more pressing issues. The high cost of feeds has resulted in the use of feeds collected from hotel kitchens or remains from the farm. These feeds are mainly energy providing and therefore protein deficiency is very likely. There are some farmers who rely on commercial feeds but some have been reported to ignore the specifications for daily feed supply in order to stretch the feeds to last longer. In Central Province, rationing of feeds was done using "Kimbo" tins without taking the weight of the feed given per pig (Tuitoek, 1984). The Livestock project appraisal report (1992) also noted that farmers were mainly using a finisher diet, meant for finishing pigs for the market, for all classes of pigs because it was cheap.

Livestock in developing countries of the world consume 2% of the total grain consumption while in the European Union the proportion is 57% and 70% in the USA (USDA, 1991). This implies that it is only food unsuitable for human consumption that is available for animal feeds in developing countries. Therefore in the face of increasing population and competition between humans and animals, reducing amounts of food are going to be used for animal feeds. Therefore sustainable livestock industry in developing countries (like Kenya), in the face of increasing population, requires mixed farms so that crops and animals can contribute to one another (Naegel, 1996). Hence animals will continue to be fed on farm wastes. This presents a strong case to encourage on-farm feed formulation using the available wastes. This may have the dual impact of encouraging more farmers to keep pigs due to reduced production costs and improving the livelihoods of the rural poor through increased agricultural income and employment.

The biggest drawbacks in the pig industry in Kenya are in the daily feed allocation per pig, feed quality and feed costs. Feed costs have been estimated to account for 75-85% of the total pig production costs in developing countries where labour is cheap (Pond & Maner, 1984). There is therefore need to identify low cost good quality sources of feed that are easily available to the over extended small scale farmer. According to VOPS (1988) the cost of feeds could be lowered and quality improved by either seeking alternative sources of raw materials for feed manufacture or promoting on-farm mixing.

Land size in high potential areas of Kenya is rapidly diminishing with population growth. This is a general trend in all third world countries. In 1975 the average land size per farmer in the third world was 0.81 hectares but this area had shrunk to 0.61 hectares by 1989 (FAO, 1990). According to the welfare monitoring survey (1994), 68% of Kenyan population are small scale farmers while 29% are landless. Since utilising crops directly for food is more economical than first converting it to meat, then most farmers are expected to give less food to animals. However there is a correlation between increasing affluence and disproportionate rise in demand for animal products due to natural desire for consumption of meat, milk and eggs when people can afford (Franzen et al., 1996). To meet this increasing demand, animals that need little space to keep are increasing in importance in high potential areas (Franzen et al., 1996; Neidhardt et al., 1996). Hence, pig and poultry farming are likely to become the choice animal enterprises in the near future.

According to Falcon et. al. (1987) the only option available to increase future production, is through increased output per hectare rather than bringing new land into production. This is important to save the forests and release pressure on fragile arid and semi-arid lands (ASAL). ASAL areas in Kenya make up to 81% of total landmass and according to FAO (1992) extending agriculture production to these areas is presently impossible due to the enormous costs of developing large scale irrigation. Kenya therefore can only hope to increase its agriculture production through intensification of production on the existing high potential land that is only 13% of total landmass. Therefore, there is an urgent need to identify ways and means of improving livestock industries that require little space such as fisheries, poultry, rabbitry and piggery to meet the growing demands for the animal products. The methods suggested to meet this goal must take into account the view that small scale farmers, who are the majority in Kenya, have less control over the environment, less access to inputs, different priorities (family and food first, production for sale second and finally risk reduction), a mixed farming system and other off-farm enterprises (Naegel, 1996). The packages availed to the farmers should therefore increase production at low cost and make maximum use of indigenous resources on a sustainable basis (Naegel, 1996). The increased production should not lead to environmental damage or pollution.

Most of the pigs are found in Central and Rift Valley Provinces where substantial amounts of grain and by-products are available. One of the problems therefore lies with the availability of a quality source of protein. The standard protein source for pigs is soybean meal. This cake is in short supply and is also expensive. Currently (1998) it is selling at 33/= per kg at Nakuru Flour Mills. Other sources of protein available (sunflower cake, cotton seed cake, maize gluten) are either high in crude fibre or lack most essential amino acids.

Another rich source of protein that may be easily available to farmers is blood from slaughter houses. In large slaughter houses, this blood is processed into blood meal for use in livestock feeds. In small scale slaughter houses slaughtering about 50 animals per day, the blood is wasted since it is not cost effective to construct a processing plant (Divakaran and Sawa, 1986). In Kenya these small scale slaughter houses are found in most urban centres and markets. Most of the blood is routinely disposed off into pits that subsequently cause environmental pollution. Taking one cattle unit to represent one beast, two pigs or three shoats (Cooke and Pugh, 1980), Kenya slaughtered 368.1 thousand cattle units in 1993 and 1298.5 thousand cattle units in 1994 (CBS, 1995). Taking a recovery rate of 12.5 kg blood per cattle unit (Cooke and Pugh, 1980) then Kenya wasted 4601.3 and 16231.8 tonnes of fresh blood in 1993 and 1994, respectively. Taking a dry matter recovery rate of 26% for fermented dry blood meal as observed in this research, then Kenya lost 1196.3 and 4220.1 tonnes of fermented blood meal in 1993 and 1994, respectively. This is a tremendous waste for a country in dire need of sources of protein for its animal feed industry. Conventional methods of processing blood are not economically viable for use in preserving this blood. These commercial methods of processing blood have also been demonstrated to result in destruction of the amino acids especially lysine (Wahlstrom and Libal, 1977). This damage has been demonstrated to be responsible for the low palatability and digestibility of commercially prepared blood meals. The extent of the destruction is proportional to the drying temperatures and the time of exposure (Hamm and Searcy, 1976). Divakaran (1987) reported a higher pepsin digestibility value and higher lysine availability in acidulated sundried blood compared to commercial blood meals.

A new method of processing this blood from small scale slaughter houses into feed suitable for pig consumption has been recommended to arrest this wastage (Tuitoek and Ayangbile, 1992; King'ori, 1996). This method is cheap, requires no advanced technology and little or no energy is required. In view of the current energy crisis in Kenya and the world in general, methods of food preservation requiring little energy given preference. This also reduces pollution due to non-use of fossil fuels and stops environmental degradation in search of fuel wood. Kenya has over 2.7 million small scale farmers (FAO, 1992). The resources and technological know-how possessed by these farmers is minimal, hence they are not capable of adapting or financing projects that are complex. Research has been reported to have poor reputation with the resource - poor farmers since the conditions at their level differ dramatically from those of the industry and research institutions (Naegel, 1996). Hence research to benefit the small scale farmers must be able to increase production at low cost, making maximum use of locally available resources and with low external input in technologies. Agricultural research should also be environmentally friendly and sustainable. Fermentation is a simple process, cheap (using wastes from sugar and meat industries) and requires no energy input which is a problem in most rural areas with no access to electricity or firewood. It is also an old preservation method that has been used by rural communities to preserve milk, make beer and fermented porridge. According to Naegel (1996) new technologies take about 10 years to be accepted by more than a third of rural farmers in non-industrialised countries. However, fermentation is common to rural communities and can therefore be easily adapted to preserve blood for livestock feed by these rural communities. Due to inadequate technological development, procedures such as freezing, canning and refrigeration are not widely used in the tropics leading to large quantities of food going to waste. Using local sources of carbohydrates such as molasses, that are readily available, fermentation can be used to enhance food security in tropical developing countries through reduced wastage (Erichsen, 1983). This can also be used to provide the much needed animal protein for the feed industry and small scale livestock farmers in particular. This new blood preservation method entails fermenting blood in 20% molasses for 14 days and sun drying to about 14% moisture content. Sundrying takes about three to five days depending on weather conditions. Therefore fermentation and sundrying may be an easy and cheap method of producing a high quality source of protein within the farm.

The method may however present several drawbacks for the farmers, that is, the fermentation process takes too long and if the farmer has to use blood meal as a major source of protein, then it may require many fermentation containers to ensure a continuous supply. Drying may also present a problem in situations of cloudy conditions. Therefore, it is necessary to determine whether there is a necessity for drying. Although fermented sundried blood meal has been used in feeding trials in pigs, the digestibility and utilisation of nitrogen in this blood meal also need to be ascertained.

The objective of this study was therefore to assess the suitability of fermented blood meal as a source of protein for growing pigs. Specifically the study was aimed at:

(a) Investigating the possibilities of creating a continuous fermentation system for blood.

(b) Assessing the quality of blood produced by fermentation through a digestibility and nitrogen balance trial.

(c) Comparing growth rates supported by fermented blood fed either in the wet or dry form.

(d) Confirming the appropriate substitution level of soybean cake with fermented dried blood meal in a grain - fish meal based diet.

HYPOTHESES.

This work therefore proposes to test the following hypotheses:

1) H_0: $\mu=\mu_0$. That the fermentation rate is not affected by the quantity of the inoculant added.

H_1: $\mu\neq\mu_0$. That the fermentation rate is affected by the quantity of the inoculant added.

2) H_0: $\mu=\mu_0$. The form of fermented blood meal in grower pig diets has no effect on animal performance .

H_1: $\mu\neq\mu_0$. The form of fermented blood meal in grower pig diets affects the animal performance .

3) H_0: $\mu=\mu_0$. Inclusion of FDBM in grower pig rations does not affect nitrogen utilisation.

H_1:$\mu\neq\mu_0$. FDBM in grower pig rations affects nitrogen utilisation.

4) H_0:$\mu=\mu_0$. Level of FDBM in growing pig diets has no effect on animal performance

H_1:$\mu\neq\mu_0$. Level of FDBM in growing pig rations affects animal performance.

CHAPTER TWO

LITERATURE REVIEW

PIG INDUSTRY IN KENYA

Introduction

The pig industry in Kenya dates back to 1904 when some exotic pigs were introduced into the country from Seychelles. In the first few years, the industry suffered from marketing problems and diseases such as the African swine fever. However, with time the industry stabilised and by 1959 it produced 100,000 pigs, 70% of them coming from large scale farms mainly in the Rift Valley. Towards independence, the industry was devastated by departure of large scale white farmers and by 1963, the total pig population had dropped to only 35,000 (Livestock project appraisal report, 1992). After independence, the production shifted to small scale farmers mainly in Central Province and Nairobi. Subdivision of large scale farms that were owned by European settlers also increased the number of small scale pig producers. By 1971 the total sales of pigs to Uplands Bacon Factory (UBF) by small scale farmers were reported to be about 50%(Tuitoek, 1984). By 1992 the percentage total output by small scale farmers was reported to be 90% with 60% coming from Nairobi and Central Provinces (Livestock project appraisal report, 1992).

With the shift of production to small scale farmers, the production slowly picked up and by 1994 the number of pigs was estimated to be 369,745 (MOALD and M, 1994). Currently the pig industry is the third largest in the livestock sector after cattle, sheep and goats. Its contribution to the economy in 1994 amounted to K£3.65 million while cattle contributed £252.71 million and sheep and goats fetched £ 37.99 million (CBS, 1995).

However, the growth of the industry under small scale farmers has mostly not been accompanied by management improvement. Generally this failure to change agriculture from extensive to intensive production has been blamed on policies such as erratic price adjustment, poor supply of inputs and decreased private and public investments (FAO 1992). This was noted in the Kenya's sixth national development plan (1987 - 1993). The plan targeted to increase production through increased incentives to farmers, promotion of agricultural research, increased extension credit and supply of inputs to small holders.

Systems of production

Most systems of production are small scale producing approximately 90% of the pigs in Kenya. These small scale systems of production can be described as intensive, semi - intensive (backyard) or free range (scavenging). The intensive systems of production are mainly in Nairobi and Central Provinces where majority of farmers have fully commercialised their production systems (MOALD & M, 1994). The farmers either grow feed or purchase commercial feeds specifically for the pigs. They make an attempt to optimise output through proper feeding, prompt marketing and provision of veterinary services against parasites and diseases. These farmers also keep high performance exotic breeds and their crosses. Herd sizes of up to 50 pigs are common. It should be noted that both Nairobi and Central Provinces are close to slaughter and processing facilities that are mostly located in Nairobi, hence this could be the main incentive for going fully commercial.

In the semi-intensive or backyard system of production, the pigs are confined in simple structures or they are tethered in the compound. The feed is mainly home made and/or swill. The breeds are either exotic pure breeds or their crosses. The average herd size is normally 2-3 sows. Marketing, mainly to local butchers, is dictated by the financial needs of the farmers. This system can be found in parts of Central and Eastern Provinces (MOALD & M, 1994).

Scavenging or free range is the traditional system of rearing pigs in the tropics (Holness, 1991). It is the simplest and cheapest. This system of production is found in Nyanza and Western Provinces of Kenya (MOALD & M, 1994). The herd size is between one to three sows. The pigs are allowed to roam freely and pick up food when and where they can. Extra feed from the kitchen may be provided if it is available. This system is characterised by low productivity, irregular breeding and high piglet mortality rates (Holness, 1991). The pigs carry heavy burden of intestinal worms mainly due to their easy access to sources of parasites such as human wastes. Worm burdens of up to 22,500 eggs per gram have been reported on the Western Kenya pigs (Tuitoek, 1984).

Feeding

Farmers have consistently claimed that commercial feeds are either expensive and/or of poor quality. Jacob (1993) attributed the low quality of feed to either lack of qualified nutritionists making feed, use of data collected in Western Europe on chemical composition of ingredients which may not be similar to same ingredients available locally or lack of appropriate raw materials and knowledge on the composition and inclusion levels of the alternative local raw materials. Over-use of by-products is another contributory factor (VOPS, 1988). This is due to shortages and high cost of ingredients such as fish meal and soybean meal.

According to the Livestock project appraisal report (1992) many farmers are using commercial feeds, but most of them use the pig finisher type of feed for all different stages of growth. The complaint of poor quality feed may therefore be partly due to the wrong use of the feeds. Some farmers buy cheap maize and wheat by-products such as maize germ and wheat bran that they mix together to form a meal. These are also at times mixed with swill or factory wastes from bakeries or just fed individually. Tuitoek (1984) reported that other wastes such as spoilt maize, sweet potato vines and skim milk were used in Central P rovince. Generally apart from the farmers who have fully commercialised their pig production enterprises, other farmers have little concern about meeting the nutrient requirement of the pigs. Pigs are first kept to clear the wastes and feed left-overs.

Housing

A few commercial farmers have constructed stone pens for their pigs, but the majority of the farmers house their pigs in wooden pens with floor made of compacted stone covered with a thin layer of soil to make it smooth and corrugated iron roofs (Livestock project appraisal report, 1992). The feeding and watering troughs were reported to be wooden in most establishments. In some permanent units nipple drinkers have been connected but in most units water is brought by buckets. In western Kenya the pigs were either simply tethered, kept in semi permanent sheds or temporary shacks made of sticks. Such houses have been described as mainly draughty and cold (Tuitoek, 1984).

Marketing of pigs

Up to 1975 Uplands Bacon Factory (UBF) was the main buyer and processor of pig products throughout the country. The company supplied farmers with gilts and feed on credit and the money was recovered from the pig sales to the company. The rest of the pigs were either sold to local butchers or small processing facilities that started coming up by 1976. After the collapse of UBF in 1987 due to financial and managerial problems its share of the market was taken up by local slaughterhouses owned by municipalities and privately owned slaughter and processing facilities located around Nairobi. With the financial and management problems of UBF, other private businesses had a chance to expand rapidly and take over the market previously controlled by UBF. Farmers' Choice was the greatest beneficiary of the UBF closure and according to the 1994 MOALD & M annual report, it handles 80% of the market. The company has a slaughter house for pigs and a meat processing plant on the outskirts of Nairobi. The company has a capacity to slaughter 60 pigs per hour or 1,800 pigs per week on a single shift. The capacity of the slaughter house is 25% under-utilised (Livestock project appraisal report, 1992). To make use of at least part of the un-utilized capacity of the factory, FC purchased and processed 4,000 head of cattle in 1991. The products of the factory include fresh pork, sausages, cured meat, ham, bacon and lard. Some of these products are exported (3% in 1991). Other processing facilities include Nairobi Airport Services, Gourmet Meat Products, Kenya Bacon Company and Kenya Cold Storage. All these facilities are located in and around Nairobi. In Nakuru Super Duka and Gilanis butchery buy pigs and process pig products.

Farmers far removed from the processing facilities or those not contracted to supply pigs to these companies, sell their pigs directly to retail butcher shops and small processors. These butcher shops slaughter and sell fresh pork directly to consumers in rural areas while small processors are capable of producing sausages and other processed meat products in small quantities ranging from 10 to 100 kg per week (Livestock project appraisal report, 1992). It has been reported (MOALD and M,1994) that farmers in Eastern Province consumed their pigs locally. The report also notes intensified investment in butcheries in Central Province especially Kirinyaga and Muranga districts where 1343 and 2184 pigs respectively were slaughtered locally in 1994. Due to existence of one major pig processor, that is FC, the pricing and general control of the industry are monopolistic. FC largely determines the producer price of the pigs with smaller buyers setting their prices around the FC's price. Today many farmers are complaining about low prices offered by the buyers. These low prices could also partly be due to the grading and quality requirements of the buyers. Due to poor feeding regimes used by most farmers the carcases obtained are largely of low quality.

Problems facing the pig industry

Contribution of the pig industry to the Kenyan economy is very small compared to cattle and sheep and goats. This has been attributed to problems such as lack of credit, low producer prices, high feed costs, internal and external parasites and lack of good quality breeding stock (VOPS, 1988; Livestock project and appraisal report, 1992; Jacob, 1993; MOALD & M,1994). One of the constraints limiting the expansion of the pig industry in Kenya is the inability of many farmers to acquire credit from which they can improve their pig enterprises and expand production. This has hindered the improvement of the industry through better housing, feeding and increased herd sizes. According to the Livestock project appraisal report (1992), the situation is worsened by the fact that most of the production is done by women who do not own land title deeds hence cannot obtain loans. More than one third of the farms in Kenya are managed by women (FAO, 1992). It is therefore important to find ways of giving loans to small scale farmers without the requirement for collateral. The Agricultural Finance Co-operation (AFC) is supposed to give credit to farmers. Other banks are required to reserve 17% of their total credit to farmers but most of them ignore this requirement (FAO, 1992). Plans are underway to provide a credit facility to be administered by AFC specifically for pig farmers (MOALD and M, 1994).

Every year the complaints about poor quality and high feed prices have persisted (VOPS, 1988, Jacob, 1993). The main reason advanced by manufacturers is shortages of raw materials and poor quality of available raw material (VOPS, 1988). Wrongful use of the manufactured feeds such as use of a specific cheap feed for all classes of pigs and resistance by farmers to spend money on feed purchases are contributing factors. Farmers using wastes from the farm and kitchen make no attempt to provide a balanced diet, hence poor performance (Tuitoek,1984, Livestock Project Appraisal report,1992).

Problems of internal and external parasites are prevalent in most farms. Animals with external parasites are treated with old engine oil smeared on the body to avoid buying expensive drugs such as Ivermectin. Internal parasites are eliminated using cheap dewormers. To eradicate internal worms completely is impractical but good sanitation, and systematic deworming can achieve satisfactory control (Pond and Maner, 1984). However in most small scale enterprises good sanitation is improbable especially with lack of piped water. Hence heavy worm infestation is common. Due to poor care of the young and poor housing, mortality rates of up to 19% have been reported (Livestock project appraisal report, 1992).

The availability of quality breeding animals has also been a constraint. Between 1976 and 1984 a project funded by Dutch government supplied farmers in Central Province with quality breeding sows. The scheme collapsed with the closure of UBF. The sources of breeding stock today are the Farmers Choice and the East African Extract Company (EATEC). Farmers far from these companies are disadvantaged. In areas far from Nairobi and Eldoret inbreeding has increased with a probable consequent reduction in productivity.

Potential of the pig industry in Kenya

The Kenyan human population continues to grow at an average rate of 3% (CBS, 1996). This has increased the pressure on available land especially in high potential areas that form about 13% of total agricultural land in Kenya (CBS, 1995). Traditional animals (cattle, sheep and goats) cannot be maintained in these small scale plots. The need for protein sources of animal origin is however increasing especially with increase in general nutritional awareness and improving standards of living. So the pig and poultry industries that have a high turnover rate and require little space are ideal for the small holder in high potential areas. The pig is the most efficient farm animal in converting feed energy to body energy and ranks third behind poultry and dairy cattle in efficiency of conversion of feed energy to protein (Pond & Maner, 1984). It is therefore imperative that efforts be made to stimulate growth in pig and poultry subsectors of livestock production to help meet the rising needs of protein sources of animal origin.

The market for pig products is already there and expected to increase. The total demand for pig meat in 1989 was reported to be 6,800 tons, but production in the same year was 4,800 tons resulting in a short-fall of 2000 tons (Livestock project appraisal report, 1992). The demand for the pig meat is reported to grow at 7% per year (Development plan 1997 - 2001). Therefore to remove the shortfall in supply of pig products and meet the rapidly growing demand, the supply must grow at a rate above 7% per annum. For such a rapid growth rate to be realised, constraints in marketing and feeding should first be addressed. Increasing the number of buyers and processors in the rural areas far removed from the large towns may help solve the marketing problems in addition to increasing the range of pig products available in the rural areas. This may be through pig producer co-operative societies and government support for local butchers.

Feed quality and its availability for pigs is the main drawback. Tuitoek (1984) reported that commercial pig producers had only a small profit margin, if any at all, due to the high costs of feed. This may be a major reason for the low population of pigs. To cut costs on feeding the author recommended use of cheap locally available by-products. VOPS (1988) recommended use of these by- products to make balanced quality feeds on the farms to avoid the problem of inferior commercial feeds. This will promote the industry by providing alternative feeds in place of expensive, inferior and sometimes unavailable commercial feeds. However, before recommending use of these by-products to the farmers, research needs to be done on their nutritional value, side effects if any, profitability and suitable levels for inclusion in pig diets.

Pig Feed resources in Kenya

Pigs are direct competitors for food with humans. Usually the excess food or food rejected for use by humans is available for the pigs in developing countries (Franzen et. al. 1996). Drought in Kenya has been reported to be a cyclic event occurring every ten years, with mild droughts occurring every 3 to 4 years. During periods of drought, there is not enough food for humans and the supply of feed for pigs is also bound to be cyclic just like the drought. In drought situations the quality of feeds drop seriously because manufacturers wholly use by-products for feed manufacture. These periodic shortages of feed in the market and quality fluctuations have been reported (VOPS, 1988; Jacob, 1993). The situation is made worse by the fact that Kenya has been having a negative per capital output for food production since 1988 (FAO, 1994).

Energy feed sources in Kenya are limited to maize, wheat and barley or their by-products. Most of the barley is cultivated under contract of Kenya Breweries Limited, hence only the rejected grains are available for the feed industry. Kenya is also a net importer of wheat hence the available wheat is too expensive for use in livestock feeds. The country produces an average of three million bags of wheat while six million bags are needed for local consumption. Maize and grain by-products are therefore the main energy sources for livestock. The production of maize fluctuates considerably from season to season. For example in 1994 the country had a serious drought necessitating importation of maize (FAO,1994), while in 1995 there was a bumper harvest of 34.3

million bags of maize. This caused the price of maize to drop to Ksh. 450/90 kg bag at farm gate level (1997-2001 development plan). This year (1997) the country has to import 7.1 million bags of maize amidst a serious drought that has led to declaration of a national disaster and the price of maize shot up to Ksh. 1000 at the farm gate level. This unreliable supply of maize implies that the livestock industry will have to look for alternative sources of energy since the traditional source that is maize, is becoming increasingly unavailable. Other energy sources such as sorghum and cassava need to be explored for use in pigs and poultry rations. These crops can grow in marginal areas that form about 81% of all the land (CBS, 1995). These crops have low input requirement in terms of fertilisers and pesticides and have satisfactory yields in the arid and semi-arid areas where maize will not do well. Therefore, they would provide alternative energy sources at lower costs and provide sources of steady incomes to populations in the marginal areas. Their use is however subject to overcoming the problem of tannins in sorghum and cyanogenetic compounds in cassava.

Protein sources of feeds in Kenya are even more scarce than energy sources. SBM is the most important protein supplement for livestock feeding especially non ruminants. It is the standard to which other protein supplements are compared. The meal has high palatability, high digestibility, high protein content, a good amino acid balance, low fibre content and a high digestible energy content (Cheeke, 1991). The meal has also a high consistency, that is, little or no variability in composition. Soybean production is low in the country and currently attempts are being made to promote the crop. Sunflower and cotton are the only crops yielding protein produced in substantial amounts in Kenya today. These two protein sources are of poor quality as feed for non ruminants.

Cotton seed meal is toxic to non ruminants due to gossypol. The effect of gossypol is cumulative with effects taking weeks to months to appear (Cheeke, 1991).The protein quality and content of the cake are lower than in SBM. The cake also has lower palatability for poultry and pigs compared to SBM. In diets of non ruminants the cake should not exceed 9% (Cheeke, 1991). Sunflower cake has a high fibre content (11-13) which along with a very low lysine content, limits its use in non ruminant diets. The cake is produced by either expeller or solvent process. The expeller process produces a cake with more fat and fibre and lower quantities of CP than solvent extracted cake. Removing the hulls using a screen improves the protein content of the meal. Replacing more than 25% of SBM by sunflower meal depress ADG (Seerley et al., 1974). Their production has however been reported to be on the decline due to poor marketing (CBS, 1995). Protein supplements of animal origin are not locally available except fish meal that is available in small quantities of variable quality due to adulterations by the suppliers (VOPS, 1988). Small phellagic fish called omena is used to make the fish meal. The fish is dried and ground without further processing. The closure of Kenya Meat Commission removed the only source of meat and bone meal and blood meal that used to be available locally.

In an effort to support livestock industry through improved feed quality and lower prices, the Government of Kenya lowered the import duty on fish meal and oil seed cakes to 10% and 20% respectively (MOALD & M, 1994). However for a permanent solution to the problems affecting the feed industry in terms of availability and quality of protein sources, there is need to produce enough oil seed to supply the cake. There is also need to look into ways in which blood and bones from abattoirs could be processed instead of being wasted as is the case in many local abattoirs. This could provide the necessary protein supplement of animal origin in animal feeds especially for non-ruminants. This would also reduce environmental pollution, promote ecosystem management as well as increase agricultural production, income and profit. Today consumers of agricultural produce are paying more for organically produced food which is free from toxic residues from fertilisers and pesticides (Naegel, 1996),

Use of blood meal in pig diets

Blood is a by-product of slaughter houses containing over 80% crude protein and 9% total lysine on dry matter basis. This blood is variously used either as human food, processed into animal feeds or simply disposed off into the sewers or open pits around the slaughter houses. In developed countries, blood, meat and bone are routinely processed into meals for use as protein supplements but in developing countries slaughterhouse waste processing industries are poorly developed and as a consequence these by-products are often wasted (FAO, 1982). In Kenya this blood is usually disposed off into sewers or open pits due to lack of processing facilities. This is a health hazard since blood is a good medium for growth of micro-organisms. Rivers and air pollution are common in rural slaughter houses where the blood is left to decompose or it is discharged into rivers. Disposal of raw blood into the sewage system can also cause blockage of sewers.

Various methods have been used to utilise the blood for animal feeds. Vat or drum drying is the traditional method of blood processing. Blood is heated at about 165^0C for 10-24 hours (Pond and Maner, 1984). The resultant meal has been found to be low in palatability and digestibility. Waibel et al., (1977) have reported CP digestibility values of as low as 55%. Lysine availability of four groups of vat dried blood meal ranged from 0 to 43%. Hamm and Searcy (1976) concluded that as temperature and time of exposure to heat increased the availability of lysine decreased. Vat dried blood meal included at 4% to replace an equivalent amount of SBM protein affected the rate and efficiency of gain (Wahlstrom and Libal, 1977). Pond and Maner (1984) concluded that vat dried blood meal can be used to replace 2-4% of the protein supplement in pig rations without affecting pig performance.

In an effort to reduce the effect of prolonged heat exposure, methods using high temperatures for a very short period have been used. In the ring process of flash drying, blood is coagulated, fluid is pressed out and solid matter is introduced into an elliptical hot air stream as small particles that are rapidly dried (Miller and Parsons, 1982). Blood is not particularly sensitive to heat damage when heated for short periods of time (Waibel et al., 1977). Ring dried blood meal has been reported to have a lysine availability of 90% for young pigs of 13-30 kg liveweight (Parsons et al., 1975). Miller et. al. (1977) reported an availability value of 70% for 9 kg young pigs while Waibel et al. (1977) have reported a range of 80 to 97% lysine availability for chicks, rats and turkeys. Average nitrogen digestibility of ring dried blood meal has been reported to be 89% in chicks (Nelson and Kirby, 1982).

In another flash drying procedure whole blood is applied in a thin film to the descending side of a rotating steam heated drum. This blood is scrapped off the ascending side as a dried sheet which is then flaked and pulverised to form a meal (Miller and Parsons, 1982). Both ring dried and rotary steam dried blood meals can be included up to 6% in pig diets to replace an equivalent amount of SBM protein (Wahlstrom and Libal, 1977; King and Campbell, 1978).

In flash drying, the exposure time to heat is variable due to varying particle size. Larger particles will take longer to dry than the smaller particles (Cook and Dumont, 1991). This longer drying period increases chances of heat damage (Kats et al. 1994b). Further processing is also necessary to achieve the desired particle size. To avoid these problems blood is atomised into particles of appropriate size and then released into a drying chamber through a nozzle or spinning discs (William's and Gardner, 1971). The temperature of the air in the drying chamber may reach several hundred degrees centigrade but that of blood particles does not exceed that of the final product (blood meal) due to evaporative cooling (Strumillo and Kudra,1986). No further processing of the final products is necessary. Feeding of spray dried blood meal resulted in improved pig performance compared with feeding flash dried blood meal (Kats et al., 1994b).This is due to a more consistent higher quality product obtained through spray drying process compared with other forms of drying. The higher quality of spray dried porcine blood meal compared to flash dried blood meal is due to the differences in processing method since similarly prepared blood meals have similar quality irrespective of species of the original blood (Kats et al., 1994b). Young pigs weighing 6.9 kg initially fed diets containing spray dried porcine blood products had a greater average daily gain (ADG) and feed intake (FI) than pigs fed diets with menhaden fish meal, soyprotein concentrate, moist extruded soy protein concentrate or synthetic amino acids (Kats et. al., 1994b). The authors also reported greater ADG and improved FI with increasing levels of spray dried porcine blood meal (0-5%) added to replace SBM in maize - SBM - dried whey diets for weaning pigs (5.8 kg). SDBM supplied readily available source of lysine for weaning pigs of 5 to 20 kg weight range. The digestibility of SDBM is also similar to that of dried whey, spray dried porcine plasma and spray dried bovine plasma (Hansen et al., 1993). However in diets containing SDBM methionine is the first or second limiting amino acid (Kats et al., 1994a). Addition of methionine in diets containing SDBM improved performance in weaning pigs (Owen et al., 1993; Kats et al., 1994b; Owen et al., 1995). Addition of spray dried blood meal in diets of weaning pigs resulted in greater ADG and increased FI even after pigs were switched to diets without blood meal (Sohn et al., 1991; Hansen et al., 1993). According to Kats et al. (1994b), the improved performance observed even after switching of diets is primarily due to improved feed intake in pigs previously fed SDBM. Kats et al. (1994b) recommended an inclusion level of approximately 2.0% SDBM in starter pig diets to maximise growth performance from day 7 to day 28 post weaning. Addition of greater than 5% SDBM in pig diets may result in isoleucine deficiency (Becker et al., 1963).

Methods of preservation and processing of blood meal that do not use heat altogether have also been used. Due to present energy crisis, the alternative energy saving processes for food preservation will become increasingly important in the future (Erichsen, 1983). A concentration of 0.1% formalin was reported to be sufficient to prevent increase in total bacterial count at 5^0C but at 16^0C, 0.65% formalin was necessary to prevent bacterial increase for 7-8 days (Walker, 1977). It was also observed that increasing levels of formalin reduced amino acid availability but no feed refusals or health problems were encountered in a feeding trial. Divakaran and Sawa (1986) reported that 3% of either sulphuric or phosphoric acid prevents putrefaction and fungal growth in slaughter house by-products. Sun dried acid treated blood had higher lysine availability (76.4%) than oven dried blood (73.4%) or commercial blood meals (63.2) (Divakaran, 1987).

Fermenting blood in 20% molasses for 14 days has also been recommended as a simple and cheap method of preserving small quantities of blood (Tuitoek & Ayangbile, 1992). Fermentation has been used to preserve foods for a long time especially in the tropics where foods rapidly deteriorate. Animal products such as milk, sausages and fish are traditionally preserved by fermentation (Pederson, 1979; Erichsen, 1983; Stamer, 1988). Excess fish and its by-products have been fermented with molasses for use in animal feeds. The rapid drop in pH with a final pH of about 4 effectively controlled the risk of poisoning and diseases from the ensiled fish meal (Erichsen, 1983). Feeding experiments have shown that the nutritive quality is good. Molasses is necessary to initiate lactic acid production leading to preservation. Experiments using fermented blood meal have shown encouraging results. 10% wet fermented blood in pig rations had no detrimental effect on the pig performance (Tuitoek & Ayangbile, 1992). Feeding trials with dry fermented blood meal used to replace half the amount of SBM in maize fish meal diets resulted in similar performance with the control. Total substitution of SBM with blood meal depressed feed intake although growth rate and feed efficiency were not statistically different from the control (King'ori, 1996).

In the fermentation process, blood is mixed with molasses and left to ferment. This type of fermentation depends on chance or random contamination with micro-organisms often resulting in products with variable quality (Erichsen, 1983). Using previous fermenting containers or small quantities of previous fermentation products, allow desirable organisms to take control of the fermentation process, impart characteristic flavour and prevent growth of undesirable organisms. Inoculation has been used in the milk and silage fermentation to speed up the process and produce a more complete fermentation (Pederson 1979,). Inoculation also produces a more complete final product with improved flavour (Erichsen, 1983). Inoculation introduces a starter culture that contains appropriate micro-organisms to the fresh food. The fermentation process is usually started by mildly acidic organisms that are eventually inhibited by their products. Then other more tolerant organisms take over. An inoculant from a completely fermented sample contains the high acid producing organisms found in the final stages of fermentation. These organisms cause rapid fermentation and fall in pH of the fresh food mainly because the lag phase of the microbial growth curve is by-passed. The superiority of the high acid producing variety of the micro-organisms leads to their rapid population build up and dominance with a consequent rapid drop in pH due to acid production (Pederson, 1979; Lindgren and Pleje, 1983). The rapid acid production and fall in pH may shorten the time required before fermented blood is ready for use in pig rations.

In fermented products that are not subjected to heat, possibilities of food poisoning are real. To ensure proper preservation and minimise health hazards rapid acidification must occur (Erichsen, 1983). This denies pathogenic bacteria the opportunity to multiply. Pathogenic organisms such as *Staphylococcus aureas, Salmonella spp* and *Clostridium spp* can only be problematic in fermented foods if they are present in large quantities in the original raw material or they got time to multiply in the initial stages of fermentation (Erichsen, 1983). Therefore use of starter cultures could help achieve a better preservation through rapid fall of pH to arrest growth of pathogens.

Fermentation in molasses is considered a cheap and efficient method of processing blood that does not adversely affect the quality of blood meal. After fermentation, the blood is dried for between three and five days before grinding to form a meal (Tuitoek and Ayangbile, 1992; King'ori,1996). Drying takes time and labour while grinding requires machinery and fuel. Bad weather can hold down the processes for a prolonged period of time. These costs and inconveniences can be avoided if it is shown that there is no beneficial effect in drying the fermented blood meal.

The main dietary factors affecting protein utilisation are its digestibility, the balance of amino acids and their availability and the amount of protein and energy supplied (ARC, 1981). Blood meal is a rich source of protein having over 80% CP and 9% total lysine but is seriously deficient in isoleucine (Pond and Maner, 1984). It is therefore possible that blood meal could be a quality source of protein for livestock if the isoleucine deficiency is corrected. However, the methods used in the processing of blood meal affect its digestibility and palatability, consequently reducing its utilisation to varying levels. Heat has been used to varying degrees in most processing methods with consequent varying levels of damage. CP digestibility of vat dried blood has been reported to be 55% (Waibel et al., 1977), that of ring dried blood is 89% (Nelson and Kirby, 1982) while that of sundried and treated blood has been reported to be 99.5% in an in vitro experiment (Divakaran, 1987).

Blood meal prepared by fermentation in molasses and then sundried is readily accepted by growing pigs even when included upto 11.5% in their rations (King'ori, 1996). This implies that there may be no palatability problems associated with fermented blood meal. Low levels of inclusion of conventional blood meal into pig rations have been recommended because of either low palatability and/or poor digestibility of the blood meal (Pond and Maner, 1984).

Several trials have been carried out to test the acceptability and possible ill effects of fermented dry blood meal when fed to pigs (Tuitoek and Ayangbile, 1992, King'ori, 1996) and poultry (Tuitoek & Ayangbile,1994). The results of these studies have been encouraging. Blood meal has several nutritional limitations some inherent to the blood itself while others are brought about by damages occurring during processing. Due to the second factor, differently processed blood meals have different inclusion levels to achieve optimum pig performance. Available information for fermented dried blood meal (FDBM) in rations for growing pigs suggests that more than 10% in pig rations depress performance (King'ori, 1996).

Digestibility.

Although fermented blood meal is used as a source of nitrogen, no studies have been done on the utilisation of nitrogen. Although blood meal from different animal species has similar nutritional quality (Kats et al.1994b), digestibility and acceptability of blood meals processed differently differ (Pond and Maner, 1984). According to Wilson (1980), data based on proximate analysis is also misleading if not accompanied by digestibility and palatability experiments.

Both in vivo and in vitro methods are used to measure protein digestibility. However, all the in vivo methods are inaccurate due to endogenous secretions and bacterial activity in the hindgut. Measurement of the endogenous secretions is difficult since it varies with type of protein, level of protein and crude fibre in the diet (ARC, 1980; Bergner, 1995). Four methods of determining digestibility are generally used. These are: (1) Total faecal collection. This method is simple but suffers from errors introduced by endogenous secretions and bacteria growing in the large intestines (ARC, 1980). (2) Ileal digesta collection. This requires surgical fitting of a cannula in the terminal ileum. Errors are introduced by endogenous secretions and some microbial activity that occur in the small intestines (Bergner, 1995). (3) Measurement of amino acids absorbed into the hepatic portal vein. The method is technically complex. The amino acids measured are both from dietary and endogenous sources. Those amino acids used in the gut wall are also not included. (4) In vitro methods. These are either chemical, biochemical or microbiological. These however have no direct application to animal nutrition. It is difficult to measure endogenous secretions since they vary with type of protein, level of protein and fibre content in the diet. Hence none of the methods available is an accurate predictor of the nutritive value of the protein sources (ARC 1980). But as far as protein quality is concerned, the determination of protein digestibility is significant mainly for comparative analysis of new or unknown feedstuffs (Bergner, 1995). Therefore any of the methods used may not adversely affect the results of the feed stuffs being compared. In this experiment total faecal collection method was used due to its simplicity.

CHAPTER THREE

MATERIALS AND METHODS

EXPERIMENT 1: Effect of an inoculant on the fermentation rate of fresh-blood molasses mixture.

Experiment 1 was designed to test the effect of an inoculant from completely fermented blood on the fermentation rate of fresh blood-molasses mixture.

Fresh blood was collected immediately following stunning of animals early in the morning and transported for a distance of 50 km to the laboratory at Egerton University. On arrival at about 11.00 am, molasses was added at a rate of 20% by weight to the blood and thoroughly stirred. One kilogram each of the mixtures was weighed into 27 two litre plastic containers. Fermented blood was added into the containers to replace equal amounts of fresh blood-molasses mixture. The innoculant had been fermented for 14 days and its pH was 4.03. The replacement rate of fresh blood-molasses' mixture ranged from 10% to 90% at intervals of 10%. Each level of replacement was replicated three times. Changes in pH were taken daily at 12.00 noon until a constant pH was obtained. This was done for nine consecutive days. A sample of the fermenting mixture was drawn after thorough mixing, diluted with an equal amount of water and the pH read. The pH was read using Digital pH meter (WTW - GmbH). The number of days taken for the pH to reach 4.20 was recorded

1.1: Experimental design.

This was a completely randomised design experiment. There were 27 containers and nine treatments which were assigned to the experimental units at random resulting in three replicates per treatment. Treatments 1-9 had 10-90% inoculant respectively.

1.2: Statistical analysis

Data were analysed using the analysis of variance for a completely randomised design. GLM procedures of SAS (1987) with the following model was used:

$$\gamma_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

where

γ_{ij} = observation

μ = overall mean

τ_i = i^{th} treatment (level of fermented blood)

ε_{ij} = Random error

Significance was declared at $p<0.05$ and differences between means were separated using the LSD procedures (Steel and Torrie 1980).

EXPERIMENT 2: Effect of form of feeding fermented blood meal on performance of growing pigs.

This experiment was designed to investigate whether there is any additional benefit to drying fermented blood meal before it is fed to the pigs.

2.1: Blood processing

Uncontaminated blood was collected from a slaughter house in 50 litre plastic containers. The blood was tapped from the slit neck of the animal to avoid contamination with the digesta or feet of the slaughter house attendants. Immediately after collection cane molasses was added to constitute 20% of the total mixture. The mixture was thoroughly stirred to ensure uniformity. The containers were then moved to a shelter and left to ferment for 14 days with daily stirring to ensure uniform fermentation. After 14 days, the blood was spread on black polythene sheets to dry. The drying temperature was about 50^{0} C on the polythene surface. The drying process took about 3 days to reach a moisture content of 14%. At the end of collection period that spread over 56 days, the last batch of the blood was not dried after fermentation. The undried fermented blood meal was incorporated into one of the rations. The fermented blood (both the wet and dry) was transported to Egerton University (50 km away) where the dry blood was ground into a meal using a hammer mill with 3 mm screen.

2.2: Diets

Two diets were formulated to contain 16% crude protein (CP) using standard ingredients. These diets also contained 6% of either wet or dry blood meal (Table 3.1). 6% blood meal was chosen since this has been shown not to affect performance. The amount of wet blood was added to the ration to make a quantity of feed to last for 3 days to avoid spoilage due to the high moisture content of the diet. The amount of wet blood meal added was calculated from the dry matter of the dry blood used to ensure equal amounts of both wet and dry blood meals on both diets. Vitamins and minerals were added to the diets to meet the NRC (1988) recommendations for growing pigs.

Table 3.1: Composition of diets for experiment 2

	DIETS	
Ingredients	1	2
maize	74.05	74.05
soybean meal	12.4	12.4
dry blood meal(DBM)	6.00	-
Wet blood meal(WBM)	-	6.00
Fish meal	5.00	5.00
premix [1]	0.1	0.1
Dicalcium phosphate	1.20	1.20
Limestone	1.00	1.00
Salt	0.25	0.25
Calculated CP	16.00	16.00
Analysed CP	15.59	15.52

[1] Chemical Composition of Premix per Kg of feed:

Vit A - 7,000 IU, Vit D3-1000 IU, Vit E- 2.5 IU, Vit K3- (Kastab)-2.0 mg, Riboflabin-4.0 mg, Nicotinic acid-10.0mg, Pantothenic acid - 5.0 mg, Pyridoxine - 1.0 mg, Folic acid - 0.3 mg, Vit B12 - 0.005 mg, Choline Chloride-50.0 mg, Antioxidant - 20 mg, Iron (Fe) 25.00 mg, Manganese (Mn) - 40.00 mg, Zinc (Zn)- 30.00mg, Copper (Cu) - 2.0 mg, Cobalt (Co) - 0.20mg, Iodine (I) - 1.10 mg, Selenium (Se) 0.075 mg,

2.3: Animals

Twelve LargeWhite x Hampshire crosses consisting of six males and six females with an initial weight of 20.6 ± 0.05 were used in this trial. Within each sex the animals were blocked into three groups on the basis of body weight Animals within each block, in each sex were randomly distributed to the two diets such that the average weight of pigs were similar between the two diets. The animals were dewormed and sprayed before the start of the experiment. Pigs were housed individually in concrete floor pens measuring 2 x 1 meters with sawdust as bedding. The feed was offered twice per day at 8:00 am and 5.00 p.m. such that there was feed in the trough at all times. Water was provided three times per day (8.00 am, 12.00 noon and 5.00 pm) in liberal amounts. Animals were adapted to the feed and surroundings for seven days before start of data collection that lasted for 35 days.

2.4: Data collection

The ingredients and diets were analysed for crude protein using the procedures of the Association of Official Analytical Chemists (AOAC, 1995). Remains in the feed trough were collected and weighed (7:30 a m) to determine daily feed intake before fresh feed was offered (8:00 am). Once every week the animals were weighed with a weighs bridge (Paul livestock scale) with an accuracy of 0.01kg. This was done before adding the morning feed. From the daily feed records, average daily intake was calculated while average daily gain was calculated from the weight records.

2.5: Experimental Design

A 2 x 2 factorial arrangement of treatments in a completely randomised block design experiment was used. The 2 factors were diet (wet blood meal vs dry blood meal) and sex (male vs female).

2.6: Statistical analysis

Data were analysed using an analysis of covariance model appropriate for a 2 x 2 factorial arrangement where initial weight was used as the covariate. GLM procedures of SAS (1987) using the following model appropriate for a 2 x 2 factorial were used. Differences in means between the diets were separated by LSD method (steel and torrie, 1980).

Model:

$$\gamma_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \epsilon_{ijk}$$

where:

μ =Mean

τi =Treatment

β_j =Sex

$(\tau\beta)_{ij}$=diet by sex Interaction

ε_{ijk} =Error

EXPERIMENT 3: Nitrogen utilisation in fermented blood meal.

The experiment aimed at determining the utilisation of nitrogen in fermented blood meal.

3.1: Diets

The blood meal used was prepared as described earlier (experiment 2). Three diets were formulated to contain 16% CP on as fed basis. A fourth diet (basal) consisted mainly of maize and contained a CP of 5.3% (Table 3.2). Where blood meal was used, it consisted 10% of the total diet. To ensure ration uniformity throughout the trial, the total amount of each diet needed was mixed prior to start of the experiment. However, for the diet containing wet blood meal, the blood meal protein was mixed to make feed for three days only to avoid mouldy growth due to high moisture since it has been shown that a moisture content greater than 16% can allow bacteria, yeast and mould to grow (Howell, 1982). The amount of wet blood added was calculated from the dry matter supplied by 10% dry blood meal to ensure equivalent amounts of blood meal in the test diets. Vitamins and minerals were added to meet the NRC (1988) requirement for growing pigs.

Table 3.2: Composition of Diets used in Experiment 3.

Ingredients	Diets			
	1	2	3	4
Maize	63.86	68.10	68.10	97.45
Soybean cake (SBM)	33.59	19.35	19.35	-
FDBM*	-	10.00	-	-
FWBM*	-	-	10.00	-
Premix	0.10	0.10	0.10	0.10
Dilcalcium phosphate	1.20	1.20	1.20	1.20
Limestone	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25
Calculated CP	16.75	16.44	16.44	5.26
Analysed CP	16.71	16.85	14.86	4.78

*FDBM - Fermented Dry Blood Meal and

*FWBM - Fermented Wet Blood Meal.

3.2: Animals

Four crossbred barrows (Large White x Hampshire) of the same genetic makeup with an average initial weight of 58 ± 3.08 kg were chosen for the experiment. The animals were dewormed against internal parasites and sprayed against external parasites before the onset of the experiment. The animals were then placed in individual metabolic cages similar to that of Wetch et al. (1964). The four experimental diets were randomly allotted to the animals according to a 4 x 4 Latin square design. There were four time periods of 12 days each and consisting of seven days precollection period and five days of total faecal and urinary collection. The animals were placed in the cages three days prior to the start of the first 12 day period to become used to the cages.

Two kilograms were allocated to each pig and divided into two equal parts, one half given in the morning (8.00 am) and the other half given in the evening (5.00 pm). The feed was mixed with an equal amount of water to form a paste before being offered to prevent spillage. Water was offered to the satisfaction of the pigs after all the feed was consumed.

3.3: Faeces and urine collection

The faeces were collected three times a day and the daily faecal collection for each pig was weighed, mixed and a 30% sample taken. The sample was then dried at 50^0C in an oven. The cumulative samples over each period and for each pig were ground and mixed in a blender before a subsample was taken for analysis. Urine was filtered through glass wool into plastic buckets which contained 25 ml of 6 N HCl to prevent ammonia losses during the collection and storage period (Herkelman et al., 1990). The total volume of urine per day was measured and a sample (2%) taken daily. The cumulative volume was stored under refrigeration until analysed for nitrogen.

3.4: Chemical Analysis

Nitrogen in the faeces, urine and feeds was determined by Kjeldahl standard procedures (A O A C, 1995).

3.5: Calculation of digestibility coefficients

Digestibility coefficients for each time period were calculated separately. The following formula was used to calculate digestibility.

Digestibility = (Nitrogen intake - Faecal Nitrogen)/ Nitrogen Intake) x 100

The N digestibility value obtained for the basal diet (4) was used to calculate the N digestibility coefficient for SBM in diet 1. The N intake and faecal nitrogen were partitioned into portions contributed by maize and SBM using the N digestibility value for maize obtained in the basal diet. From the nitrogen intake and nitrogen excreted originating from SBM, then the digestibility coefficient for nitrogen in SBM was calculated. Using digestibility coefficients for maize and SBM obtained from diets 4 and 1, the N digestibility values for blood meal in diet 2 and 3 were calculated. In doing the calculations it was assumed that the individual ingredient digestibilities are the same when fed together as when fed alone.

3.6: Experimental Design.

The experimental design was a 4 × 4 Latin square. There were four experimental units, four treatments and four time periods.

3.7: Statistical Analysis

ANOVA appropriate for Latin Square design was used for data analysis. GLM procedures of SAS (1987) were used. Means were separated by LSD method (Steel and Torre, 1980).

The model used was:

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \Upsilon_k + \in_{ijkl}$$

Where:

μ = Overall mean

α_i = Row effect

β_j = Column effect

Υ_k = Treatment effect

$\in_{ijki}$ = Random error

EXPERIMENT 4: Optimal inclusion level of fermented dry blood meal in grower pig rations.

The experiment was designed to determine the optimum inclusion level of FDBM in growing pig rations.

4.1: Diets

The dry blood meal used was a part of the batch used in experiments two and three. Ground wheat was used as the energy source. The diets were formulated to contain 16% crude protein (CP) on as fed basis (Table 3.3).

Table 3.3: Composition of diets used in the experiment 4

Ingredients	Diets			
	1	2	3	4
Wheat	75.31	75.92	76.56	77.42
Soybean meal (44% CP)	12.14	9.59	6.88	4.23
FDBM	5.00	7.00	9.00	11.00
Fishmeal (Omena)	5.00	5.00	5.00	5.00
Dicalcium phosphate	1.20	1.20	1.20	1.20
Limestone	1.00	1.00	1.00	1.00
Premix	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25
Calculated CP	16.00	16.02	15.99	16.01

Proximate composition (Air Dry)

Diets	1	2	3	4
Dry matter (DM)	90.3	90.52	90.00	89.14
Ether extract (EE)	2.50	3.39	2.44	4.00
Ash	6.35	7.37	6.50	7.85
Crude fibre	4.85	4.92	3.33	3.21
Nitrogen free extract (NFE)	58.12	56.68	59.01	55.53

4.2: Animals

Sixteen Large White x Hampshire growing pigs equalised on sex with an initial average weight of 21.86 ± 5.92 were used for the experiment. The animals were blocked based on initial weight and by sex. The treatments were then randomly distributed within each block. Individual pigs were housed in concrete floor pens measuring 1 x 2 meters with sawdust bedding. Before the start of the experiment a five day adaptation period was allowed during which the animals were gradually introduced to the test diets. The animals were also dewormed during the adaptation period. Food was offered twice per day to ensure there was feed in the trough throughout. Water was offered three times a day until animals could not consume anymore during each watering period.

The experiment was a completely randomised block design. There were four treatments with four replicates each.

4.3: Data Collection

Food remains in the trough were collected and weighed every morning before fresh feed was offered. The animals were weighed using a weigh bridge (Paul Livestock weigh bridge) once a week. The experiment lasted for 32 days. Feed intake was calculated from the difference between feed offered and that remaining in the trough at the end of the day. These figures were used to calculate the average daily feed intake (FI).

4.4: Chemical analysis

Ingredients were analysed for proximate composition in accordance with A O A C (1995) procedures.

4.5: Statistical analysis

The data was analysed by GLM procedure of SAS (1987) using an analysis of covariance model where initial weight was used as a covariate. Means were considered significant at 5% level and were subsequently separated by least significant difference (LSD) method (Steel & Torrie, 1980). The model used was:

$$\gamma_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \Upsilon_k + \in_{ij}$$

where:

μ = Overall Mean

τ_i = treatment effect

β_j = Sex

$(\tau\beta)_{ij}$ = Interaction

Υ_k = Initial weight

$\in_{ij}$ = Random Error

Regression analyses were carried out for the responses on FI, ADG and FE to different levels of FDBM. Derivatives of these values were taken to establish the optimum levels of inclusion.

CHAPTER FOUR

RESULTS AND DISCUSSION

Experiment 1:

The results of the time taken for the pH of the mixture to reach 4.2 is shown on table 4.1. A pH of 4.2 was used as a reference point as shown by King'ori (1996). pH for treatments 1 and 2 dropped from 6.4 to 4.2 on day one and thereafter hardly changed. Treatments 3, 6, 7, 8 and 9 took three days each to reach a pH of 4.2 while treatments 4 and 5 took 5 and 4 days, respectively, to reach same pH. The fermented blood from which the inoculants were obtained had a pH of 4.03. The fermentation process is regarded to be complete if a pH of 4.2 or below is achieved (Tuitoek and Ayangbile, 1992; King'ori, 1996). King'ori (1996) reported that a pH of 4.2 was attained in 7 days and only changed with minor points in the next one week. The fresh blood-molasses mixture (control) had an initial pH of 6.39 which rose to 6.64 after 24 hours (figure 4.1). The pH drop for the next 48 hours was rapid but it took 7 days to achieve a pH of 4.2. This is in agreement with the fermentation pattern reported by King'ori (1996) for fresh blood-molasses mixtures.

Table 4.1: Effect of addition of an inoculant on time taken to reach a pH of 4.2 or below

Treatment	1	2	3	4	5	6	7	8	9	SEM
Inoculant (%)	90	80	70	60	50	40	30	20	10	-
Blood+M[1] (%)	10	20	30	40	50	60	70	80	90	-
Time (days)[2]	0.33[d]	0.67[d]	2.67[c]	5.00[a]	4.00[b]	3.00[c]	3.00[c]	3.00c	3.00[c]	0.192

[a b c d] means with the same superscript letters are not significantly different

M [1] Molasses

[2] Time taken for the pH to reach 4.2

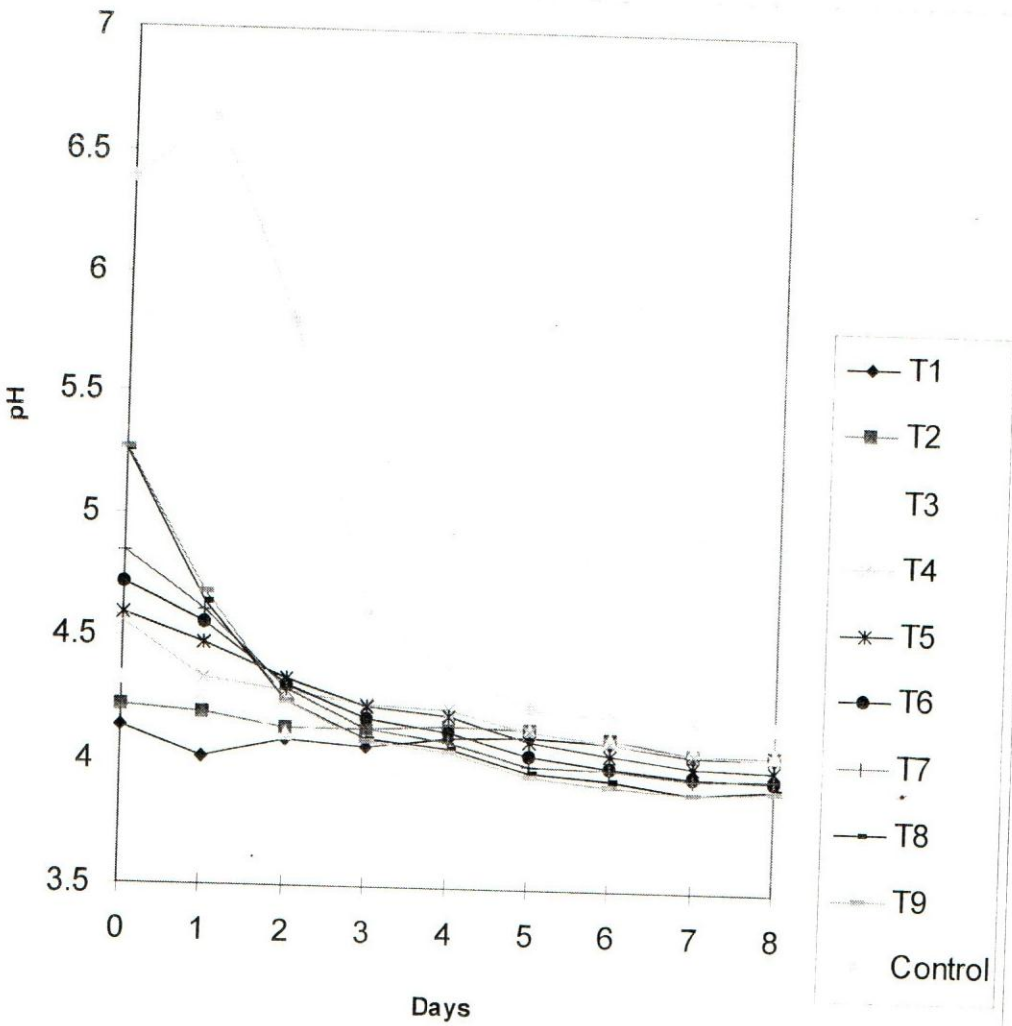

Figure 4.1: pH change over time in inoculated fresh blood-molasses mixture

The slight increase in pH in the control was due to the initial breakdown of proteins with production of ammonia. This may have been caused by the putrefactive micro-organisms initially in the blood. Further rise in pH was prevented as the fermentative micro-organisms took over with resultant acid production and drop in pH. The acid produced also inhibited further growth of the putrefactive micro-organisms resulting in preservation. Fermentation is a process by which a change is produced as a result of one or more species of micro-organisms (Pederson, 1979). The type of fermentation that occur varies from place to place depending on environmental factors such as sanitary conditions and prevailing temperatures. Physical and chemical changes occur during fermentation but the nutritive value of the culture is largely retained (Pederson 1979; Lindgren and Pleje, 1983). The nutritional quality of the culture has been reported to improve due to partial hydrolysis and synthesis that occur during fermentation (Simhaee and Keshavanz.; 1974, Shahani and Chandani, 1977). It is for this reason that yoghurt protein is superior to milk protein (Shahani and Chandani, 1979).

The micro-organisms involved in fermentation are mainly yeast and lactic acid bacteria. Yeast produce alcohol in the absence of oxygen but completely oxidise sugar to carbon dioxide and water in the presence of oxygen. Lactic acid bacteria do not require oxygen and convert sugars to lactic acid with little caloric change. Both lactic acid bacteria and fermentation yeast are microaerophilic and require similar conditions, hence in natural fermentations, they will be found growing together resulting in acid-alcoholic fermentations (Pederson 1979). With growth of the micro-organisms, acids, alcohols, carbon dioxide and other fermentation products accumulate and become toxic to the micro-organisms hence terminating the fermentation. The termination of fermentation may also occur due to depletion of nutrients required for growth of micro-organisms, mainly sugars. It has been shown that to achieve constant pH in fermentation of blood, 20% or more of molasses is required (Tuitoek and Ayangbile 1992, King'ori, 1996).

The acidity produced by fermentation in foods lowers the pH to levels intolerable to most other bacteria including pathogens. King'ori (1996) reported no bacterial growth in blood meal fermented for 14 days and sundried. Other researchers have achieved sterilisation of fermented products at or above a pH of 4.2. Caswell et al. (1977, 1978) reported that ensiling broiler litter with high moisture corn grain (final lowest pH obtained was 4.2) or added water (final lowest pH was 5.43) was effective in destroying potential pathogenic organisms. Similar results were obtained by Berger et. al. (1981) after ensiling swine wastes with ground orchard hay (final lowest pH obtained was 4.5 for 50:50 mixture) or ground corn (final lowest pH obtained was 4.2). Cornman et al. (1981) also reported complete elimination of pathogenic organisms in cattle wastes ensiled with straw. The organisms most commonly discussed as potential risks in connection with fermented food products are *Staphylococcus aureus*, *Salmonella spp*, and *Clostridiam spp* (Erichsen,1983). pH values of 4.0-4.5 have successfully eliminated *Salmonella* within three to four days in laboratory silos containing 45% corn, 15% corn forage and 40% cattle manure (McCaskey and Anthony, 1975). *Clostridiam spp* cannot grow in pH levels below 4.6 (Gould, 1983) while *Staphylococcuss* cannot grow below a pH of 4.2. Undesirable organisms, such *Escherichia coli, Brucella, Bacillus, Salmonella*, and *Clostridium* cannot grow in acid environment produced by lactic acid bacteria even though they may survive the acidity (Pederson, 1979; Erichsen 1983;

Stamer, 1988). Complete elimination of pathogenic organisms has been reported, in fermented fish and fish waste products (Lindgren and Pleje, 1983), and in fermented school kitchen wastes (Watanabe, 1982). Lactic acid has both bactericidal and bacteriostatic effects (Smulders, 1986). Low pH extends the lag phase of acid sensitive micro-organisms eventually resulting in death of the micro-organisms. Fermentation produces organic acids such as lactic, acetic, propionic and butyric acids that are responsible for preservation. It is the undissociated molecules of organic acids that are responsible for the antimicrobial activity. Low pH increases the proportion of the undissociated organic acids hence improving preservation (Gould et al., 1983; Lindgren and Pleje, 1983; Smulders, 1988). Caswell et al. (1978) reported an increase in pH of poultry wastes ensiled at 22% moisture due to failure of fermentation to occur with resultant increase in liberation of ammonia. Treatments with 40% inoculant or below had a very rapid fall in pH as shown in Figure 4.1. Their pH fell to below 4.0 in 7, 6, and 5 days for treatments with 40, 30, 20, and 10 inoculant respectively. Micro-organisms require appropriate moisture and soluble carbohydrates for growth. Addition of fresh blood-molasses' mixture provided these requirements hence the micro-organisms in the starter culture rapidly multiplied.

The type of micro-organisms found in the final stages of fermentation are more acid tolerant than those found in the initial stages (Pederson, 1979). Hence they tolerate higher degrees of acidity than initial fermentation micro-organisms consequently resulting in lower final pH than the initial inoculant sample or the final pH reached by the control. Lindgren and Pleje (1983) reported rapid fall in pH after inoculating fish with fermented cereals. The results obtained herein therefore are in agreement with the observed changes in pH due to addition of an inoculant to a fresh sample. The remnants of a previous successful fermentation (starters) are usually added at a level of 1 or 2% to new batches (Muller, 1988).

In treatments 1 and 2, addition of the inoculant (90 and 80 % respectively) dropped the pH from neutral to about 4.2 within a few hours and remained more or less constant after that. Although a few spores forming bacteria may grow at a pH of 4.0 to 4.2 their spores cannot germinate at this low pH (Pederson,1979). It is possible that the bacteria in the fresh blood-molasses' mixture never multiplied at all due to the large quantity of acid introduced by the inoculant. This amounted to preservation through addition of organic acids. The amounts of fresh blood-molasses' mixture added were only 10 and 20% for treatments 1 and 2 respectively. This plus the low level of moisture and soluble sugars added may have caused the insignificant fermentation to occur. The little soluble sugars were depleted almost immediately with little resultant fall in pH below 4.2. Harmon et al. (1975) have reported that the higher the soluble carbohydrate levels, the lower the final pH achieved. This is evidenced by the final pH of below 4.0 achieved in 7, 6, and 5 days for treatments with 40, 30, 20, and 10% inoculant respectively. The increasing levels of soluble carbohydrates availed by increasing amounts of fresh blood-molasses' mixture added, allowed rapid growth of micro-organisms with accompanying rapid acid production and consequent fall in pH.

Treatments 4 and 5 had intermediate amounts of soluble carbohydrates that were more than for treatments 1 and 2 but less than treatments 6, 7, 8, and 9. The reasons for the low rate of pH change observed in these two treatments are not apparent. Moisture content affects microbial growth. Caswell et al. (1977, 1978) have reported that increasing moisture content increased the extent of fermentation and final levels of lactic and acetic acid produced. The moisture content of all the treatments was not measured. The fast rate at which treatment 3 achieved a pH of 4.2 (2.67 days) could have been due to a combination of the high quantities of acid introduced by the 70% inoculant added and the acid produced from fermenting the substantial amounts of soluble sugars added by the 30% mixture of fresh blood and molasses added.

From the results of this study, it takes three days for fresh blood-molasses' mixture with between 40% and 10% starter culture to be ready for use while fresh blood-molasses' mixture with 60 and 50% inoculant takes five and four days respectively to be ready. Mixtures with 10 and 20% fresh blood-molasses can be used almost immediately since no appreciable change in pH occurs. For practical reasons mixtures with 30% fresh blood molasses can be used after three days. Therefore, it may be advantageous to replace between 60% and 90% fermented blood from the fermenting container. This will have the dual advantage of causing a rapid acidification and achieving a much lower final pH than 4.2.

Inoculation can be used to reduce the number of fermenting days to five or less depending on the quantity of the inoculant used. One fermenting container can also be used to supply fermented blood if less than 20% of fermenting mixture is drawn daily. Inoculation has been reported to improve the quality of final product through improved flavour and preservation. This aspect needs to be investigated in fermented blood meal.

Experiment 2:

The performance of pigs as influenced by the diets and sex of the animals is shown in Table 4.2 . There were no significant (P>0.05) interactions between sex and diet in any of the parameters measured hence only the main effects are shown. Average daily gain was similar for the two diets. ADG for both diets was about 0.8 Kg although dry blood meal resulted in a slightly lower ADG. Using wheat-soya bean meal based diets with 5.9% ring dried blood, King and Campbell (1978) obtained similar growth rates with the control while Walstrom and Libal (1977) reported a growth rate of 0.69 Kg for corn-soybean diets with 6% rotary steam dried blood meal. These results might be interpreted to imply that fermented blood meal (dried or wet) gives satisfactory performance in growing pigs. Its quality is also comparable to rotary and ring dried blood meals for growing pigs. There was no statistical difference in ADG between males and females, although the females tended to grow faster (2.2%) than the males.

Feed efficiencies were not significantly different (p>0.05) for both diets but females utilised the feed more efficiently than males. Due to better feed efficiency the females also had a better gain to feed than the males. Boars and gilts have been reported to have a better feed conversion efficiency than castrates (Fuller et al.; 1976 Fuller, 1980). This is because androgens and oestrogen in entire males and females have anabolic effects (Kay and Houseman, 1974). Castration of males and ovariodectomy in females have a retarding effect on growth rate. Hence the superior feed efficiency observed for females in the present study is not suprising.

Table 4. 2: Effect of diet and sex on performance (kg)

Diet	sex	ADG	FI	FCR
Dry blood	-	0.772	1.578	2.044
Wet blood	-	0.811	1.828	2.254
-	Male	0.783	1.799	2.297
	Female	0.800	1.607	2.007
SEM	-	0.036	0.071	0.039
Significance				
Diet		ns[1]	*	ns
Sex		ns	ns	*
Diet × Sex		ns	ns	ns

[1] Not significant

* Significant ($p<0.05$)

However castrates eat more food than either gilts or boars and can therefore compensate for the low efficiency through increased intake (Fuller, 1980). In this experiment the castrates tended to eat more than the females (12%) and this could have been responsible for the similar ADG reported in both sexes.

The results indicate a significantly ($p < 0.05$) higher feed intake in the diet with wet blood meal. This consequently resulted in a tendency for slightly higher ADG with a slightly poorer feed efficiency. The higher intake for the diet containing wet blood meal could mean better palatability for the wet blood meal compared with dry fermented blood meal. Drying may have lowered the acceptability of the fermented blood meal. The diets with the wet blood meal had higher moisture content than the diets with the dry blood meal. The higher moisture content supplied additional water to the pigs since water was not connected to the pens. This could also have resulted in higher intake of the diet with wet blood meal. However, the results obtained from experiments on feeding various mixtures of feed water ratio are variable and not conclusive (Pond and Maner, 1984).

From the results of the current study, it is apparent that the added costs of drying and grinding the fermented blood meal did not bring noticeable improvements on feeding quality of the meal. Infact it may be advantageous to feed fermented blood meal in the wet form. Therefore, the extra costs and inconveniences that may be experienced in the drying process can be termed as unnecessary. The only luxury forgone in not drying and grinding the blood meal is the advantage of mixing large quantities of feed at once. Under practical situations it is necessary to mix small amounts of the feed to last 2-3 days to avoid spoilage due to the high moisture content of the resultant diet. It may be of importance to investigate how long fermented wet blood meal will stay before spoilage under natural conditions without refrigeration or vacuum storage.

Experiment 3:

The results of dry matter (DM) digestibility of the diets and the utilisation of nitrogen are shown on Table 4.3. DM digestibility for the three test diets and maize were high. The DM digestibility in the maize-soybean meal diet was significantly higher ($P<0.05$) than diets 2 and 3 that contained fermented blood meal although the absolute difference was small (89 vs 87). Hansen et al (1993) also observed a dry matter digestibility of 86.3% when 6.6% spray dried porcine blood meal was added to a diet for young pigs. Since addition of fermented blood meal did not affect the digestibility of nitrogen, the depression in DM digestibility is therefore not due to a change in the source of nitrogen but due to other nutrient(s). The addition of molasses might have influenced the digestibility of carbohydrates leading to the depressed DM observed. Diet 4 consisted primarily of maize plus minerals and premix. The observed DM digestibility of maize in this experiment (88.7%) is in agreement with results obtained by other researchers. Sullivan et al. (1989) reported DM digestibility of 89% for 10.2 CP corn, 90% for 8.8 CP corn and 89% for 7.6 CP corn for 35 kg pigs, and Lin et al. (1987) had reported DM digestibility of 90.5% for corn for 35 to 55 kg pigs. The DM digestibility of maize-SBM diet (1) obtained in the present study (89.3 %) is similar to the results obtained by other workers.

Table 4.3 :DM Digestibility and Nitrogen utilisation in the experimental diets.

ITEM	DIETS				
	1	2	3	4	SEM
DMD (%)	89.32[a]	87.49[b]	87.19[b]	88.73[ab]	0.489
N dig (%)	88.33[a]	84.86[a]	86.98[a]	66.53[b]	3.078
NI (g/day)	50.04[a]	52.31[a]	44.69[a]	14.49[b]	3.226
Excreted faecal N (g/day)	5.84[b]	7.92[a]	5.82[b]	4.85[b]	0.518
Excreted urinary N (g/day)	24.84[a]	22.27[a]	17.72[b]	8.61[c]	1.129
NR (g/day)	19.36[a]	22.12[a]	21.15[a]	1.03[b]	3.514
BV (%)	43.80[a]	49.83[a]	54.41[a]	10.68[b]	8.169

[a, b] Figures within the same row with different superscripts are significantly different.

Herkelman et al. (1990) reported DM digestibility of 86.7% for growing pigs (70 kg) while Berger et al. (1981) have reported a digestibility coefficient of 90% for maize-SBM diets for 95 kg gilts. Kays and Derbarthe (1974) had reported a slightly lower value of 80.7% for growing pigs. In an experiment with weaning pigs (5.3 kg) Hansen et al. (1993) reported a DM digestibility of 86.3% for maize-SBM-dried whey diets containing 5% porcine blood. It appears therefore that addition of blood meal in any form depresses the overall digestibility of the diet although the digestibility of 87% obtained in the present study is still high.

The digestibility of N was similar ($P>0.05$) among the three test diets but significantly lower ($P<0.05$) for the basal diet. The digestibility of N in the SBM-Maize diet was 88.3%. This value is in agreement with values reported by Berger et al. (1981) and Herkelman et al. (1990) who reported N digestibility coefficients of 87% and 84.4% for 95 and 20 kg pigs respectively. Unlike the depression observed in DM digestibility, substitutions of SBM with either FWBM or FDBM did not affect the digestibility of N in the diets. Hansen et al. (1993) reported a N-digestibility of 79.4% in maize-SBM diets containing porcine blood. However, the digestive systems of the animals used (5.3 kg) might not have developed fully hence the slightly low figure reported. This digestibility figure reported was also similar to that of maize-SBM diets with either skim milk, porcine plasma, meat extract or bovine plasma. The digestibility of N in maize was 66.5% in this experiment. This value is rather low compared to literature values. Lin et al. (1987) reported a value of 85.6% for N digestibility in pigs weighing 39 to 55 kg. The reasons for the low figure obtained here are not apparent.

Apart from diet 4 (maize) all the three test diets provided similar amounts of nitrogen per day although diet 3 provided a slightly lower nitrogen intake per day than diets 1 and 2. This could have been brought about by the non uniformity of moisture content in the wet blood meal. This could then have led to under estimation of moisture content of the wet blood used. This resulted to overestimation of DM of wet blood meal leading to lower actual amount (DM) of wet fermented blood meal (FWBM) mixed with other ingredients. Consequently this resulted in lower percentage crude protein in diet 3 compared to diets 1 and 2. The slightly less nitrogen intake for diet three resulted in less total excreted N (23.54g) in diet 3 than in diet 1 (30.68g) or diet 2 (30.2g). These results confirm the findings by Quiniou et al. (1995) who reported increasing N excretion with increasing N intake. More nitrogen was lost through the urine than through the faeces just like in other studies (Quiniou et al., 1995). Diet 2 had higher faecal nitrogen loss than diets 1, 3 and 4. Urinary N loss was similar for diet 1 and 2 but significantly lower ($p<0.05$) for diets 3 and 4.

Nitrogen retention (NR) was similar for the three test diets but significantly lower ($P<0.05$) for the basal diet. The amount of nitrogen retained when pigs consumed the basal diet was nearly zero because the total nitrogen was only slightly above that required for maintenance. The daily N requirement for maintenance is about 6g for the size of pigs used in this experiment (Carr et al, 1977) resulting only in a small positive nitrogen balance. There was a tendency to improved NR by addition of blood meal in the diet since after substitution of SBM, NR changed by 14.3 percentage points for the FDBM and 9.3 percentage points for the FWBM. CP digestibility values obtained through faecal collection are higher than true digestibility values due to hind gut bacterial degradation (ARC, 1981; Tanksley and Knabe, 1984; Bergner, 1995). However the microbial activity of the hind gut has no effect on the nitrogen retention (Misir and Sauer, 1982). The NR solely depends on the balance of amino acids that determine the level of blood urea hence the amount of nitrogen excreted via the urine and faeces. The NR therefore is a measure of the amount of nitrogen used for protein deposition. This is dependent on matching the nutrients supplied to the nutrient required by the recipient animal as well as the growth potential of the animals to genotype, sex and physiological status of the animals (Quiniou et al., 1996). Partial replacement of SBM with fermented blood meal did therefore not adversely affect the amount of nitrogen used for protein deposition.

The observed NI was similar for the test diets but significantly lower ($P < 0.05$) for the basal diet where pigs received only 14.49 g N per day. The level of dietary CP does not affect faecal N but has significant effect on urinary nitrogen (Quiniou et al., 1995). The CP in diet 3 was slightly low and consequently NI for the same diet tended to be lower than in diet 1 and 2. This may consequently have resulted in significantly lower urinary N in diet 3 than diet 1 and 2. The faecal nitrogen for diet 3 was similar to diet 1 ($P > 0.05$) but significantly lower than diet 2. The reasons for higher faecal N for diet three were not apparent. Faecal N can only be affected by crude fibre content in the diet. The fibrous substances, through adsorption and absorption, carry amino acids, peptides and other nitrogenous compounds along the digestive tract consequently lowering true digestibility (Bergner, 1995). Fibre also increases the metabolic faecal nitrogen (MFN) through abrasion of intestinal wall. Fermentable CF and other carbohydrates in the hind gut also increase faecal nitrogen and reduce urinary nitrogen through increased bacterial protein synthesis using endogenous urea. In this experiment the CF of the diets was not analysed. However the faecal N for diet 2 was significantly higher ($P < 0.05$) than that for diets 1 and 3, although there is no reason to expect its CF to be higher than the other two diets.

The apparent biological values (BV) were similar among the test diets but significantly lower ($P<0.05$) for the basal diet. Substitution of SBM with either FDBM or FWBM however tended to improve the BV. The BV improved by 14% and 24% respectively after addition of dry and wet fermented blood meal respectively. BV is a good measure of protein quality (ARC, 1981). It is actually the most meaningful scientific attempt to arrive at a protein evaluation in a biological experiment when a comparison between feed proteins is desired (Quiniou, et al., 1995). BV portrays the protein retention effect and protein replacement effect of the absorbed amino acids. BV cannot however be calculated for individual component of feeds since it is not additive but depends on the balance of amino acids in the diet and is related to the requirements of the animal for certain performance. In this experiment it appears that maize-SBM diets have similar BV and therefore utility to the animal as maize-SBM plus fermented blood meal diets. Substitution of SBM with either FDBM or FWBM does not diminish the protein quality of the maize-SBM diet for growing pigs containing 16% CP. In fact it appears that there was a tendency for the quality of the diet to improve.

The individual ingredient digestibilities, except for maize which was determined directly, were calculated by difference according to the procedures described by Schneider and Flatt (1975). The method used assumes that digestibilities of nutrients in individual feedstuffs are additive and therefore are the same whether fed together or individually (Livingstone, 1981). In diets with fibrous or antinutritional factors the assumption is not true due to associative effects (Livingstone, 1981). However in diets of non ruminants where the fibre contents are low, the true associative effects are hard to establish due to technical and biological errors (Schneider and Flatt, 1975). Fernandez et al. (1986) also concluded that the associative effects in pigs though significant were of negligible magnitude such that the deviations due to these effects are of no practical significance.

The digestibilities of N in SBM, FWBM and FDBM shown in Table 4.4 were similar for the three sources. The digestibility of N in maize was significantly lower ($P<0.05$) than N digestibility in the three protein sources The observed N digestibility in this experiment was lower than expected. Lin et al (1987) reported a value of 85.6% and Tuitoek (1994) a value of 85.7% in corn respectively as opposed to 66.5% for maize in this study. The reasons for the low value obtained here are not apparent although differences in variety cannot be discounted. The digestibility of N in SBM obtained in this study (91.6%) is similar to observations in other studies (eg Tuitoek, 1994). Tanksley and Knabe (1984) have also reported literature values varying between 88.6% and 92.0% for similar cakes (44% CP, press extracted). Therefore, the value obtained in this experiment (91.6%) is in agreement with literature values obtained for 44% CP press extracted cake. This also confirms the validity of the assumption that associative effects were negligible.

Table 4.4: Nitrogen digestibility in maize, SBM, fermented dry blood meal (FDBM) and fermented wet blood meal (FWBM) and selected literature values.

source	N digestibility (%)			Method of drying[1]
	Maize	SBM	Blood meal	
Current study	66.5	91.6	85.3	Sundried (FDBM)
current study	-	-	87.3	Not dried (FWBM)
Waibel et al.1977	-	-	55.0	Vat dried
Nelson and Kirby. 1982	-	-	89.0[2]	Ring dried
Sauer et al.1982	-	92.0	-	-
Lin et al. 1987	85.6	-	-	-

1 This refers to the method of drying blood meal used

2 average of individual amino acid digestibilities used

Blood is usually processed by methods that involve heat. Heat and pressure have been associated with damage of proteins to varying extents depending on duration and intensity of heating (Hamm and Searcy, 1976; Maurine, 1981; Batterham et al., 1986a, 1986b; Batterham, 1992). This leads to a fall in BV and digestibility (Batterham, 1992). Severe heating leads to formation of complexes that cannot be digested hence they pass out with faeces (Maurine, 1981). Vat dried blood meal has been reported to be severely damaged with CP digestibility value as low as 55% and lysine availability of 0 to 49% (Waibel et al., 1977). The application of high temperatures for a very short period of time has resulted in a high digestibility and lysine availability. A digestibility of 89% in flash dried blood meal in chicks has also been reported (Nelson and Kirby, 1982) with a lysine availability ranging from 80 to 97% for chicks, rats and turkeys (Waibel et al., 1977). The calculated digestibility of N in FDBM and FWBM for pigs in this study is close to the N digestibility in flash dried blood meal reported by Nelson and Kirby (1982) for chicks.

Mild heat has been reported to form sugar complexes that are digestible but not utilised by the animal, hence excreted in urine (Batterham, 1992). The extent to which different species utilise heat damaged feeds is also variable (Batterham et al., 1986a). Therefore for heat treated protein feeds digestibility alone could be a misleading measure of quality since the absorbed compounds may not be available to the animal. Batterham (1992) reported that for heat damaged meals, availability falls to a greater extent than digestibility (ileal) while for high quality meals ileal digestibility and availability are similar to digestibility. The BV of FDBM and that of FWBM are 20 and 28 percentage points above the BV of maize-SBM diet although the digestibility of the latter is significantly higher than the other two test diets. This is in agreement with Batterhams' (1992) views that heat affects availability more than digestibility. The diets with FDBM and FWBM had lower digestibility than diets with SBM only but their utilisation tended to be better.

The results indicate that:

- Substitution of SBM with blood meal depresses DM digestibility of the diet significantly but nitrogen digestibility is not affected.
- BV value of the diet is similarly not affected by substituting SBM with blood meal
- Nitrogen digestibilities in FWBM and FDBM are high and similar.
- Growing pigs utilise N in FBM as efficiently as N in SBM.

Experiment 4:

The results of the influence of level of FDBM and sex on pig performance are presented on Table 4.5. The analysed CP of the diets was higher than the calculated values. This could have been as a result of variability of CP in wheat whereby a low figure of 9% was used in diet formulation. The pigs on diet 4 had irregular feed intake in one week and then compensated the following week. This resulted in low growth rates for one week followed by high growth rates the following week. (Figure 4.2).

Table 4.5: Influence of level of fermented blood meal and sex on pig performance.

Item	Pig performance		
	ADG (kg)	FI (kg)	FCR
Level of Blood meal			
5%	0.654	1.390^{bc}	2.10
7%	0.690	1.438^{ab}	2.07
9%	0.694	1.490^{a}	2.15
11%	0.609	1.266^{c}	2.02
Sex			
Female	0.624^{a}	1.325^{a}	2.10
Male	0.700^{b}	1.468^{b}	2.07
Pooled SE	0.027	0.039	0.050

$^{a, b, c}$ Means with different superscripts on the same column are significantly different

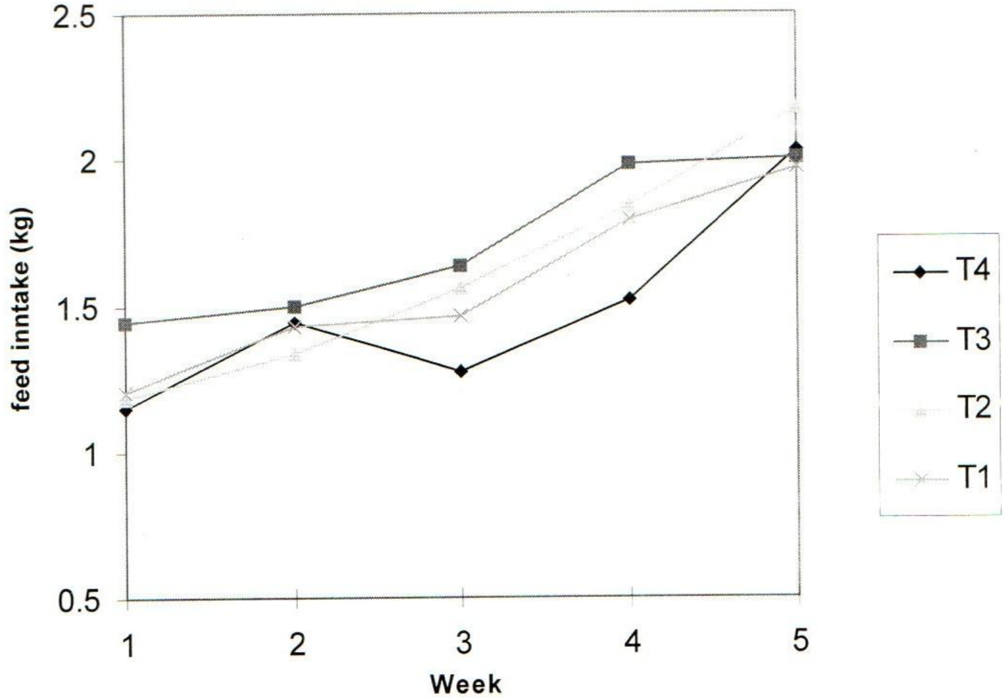

Figure 1: Average weekly feed intake for the experimental diets

There were no significant (P>0.05) sex by diet interactions in this trial. The ADG in the four diets were similar (P>0.05) although diet 4 tended to have a lower ADG than the other three diets (Table 4.5). Pigs on diet 2 (7% FDBM) and 3 (9% FDBM) had similar feed intake (P>0.05) which were higher than in diet 4 (11% FDBM). The ADG for diet 1 (5% FDBM) was intermediate. King and Campbell (1978), using pigs of a similar liveweight range (21 kg; entire males) reported more efficient growth rates for 5.9 or 8.9% flash dried blood meal compared to 3% or 11.8% flash dried blood meal in wheat-SBM-Meat and bone meal diet although the addition of more than 8.9% blood meal significantly depressed feed intake. The authors explained the drop to be caused by isoleucine deficiency which could not be overcome even by increasing intake through flavour addition. The cause of the decreased intake in this experiment at above 9% FDBM was not established. King'ori (1996) also reported a tendency to depress feed intake with a total substitution of SBM with FDBM (11.5%) in maize-SBM-fishmeal diets. The results of King and Campbell showed a linear decrease in FI with increasing levels of flash dried blood meal, while in this experiment increasing FDBM upto 9% resulted in a linear increase in FI.

Increasing levels of blood meal from 9% to 11% depressed ADG by 14% although it was not statistically significant (P>0.05). This could be due to the significant depression in FI observed on increasing the FDBM from 9% to 11%. These results are in agreement with the results of King'ori (1996) who reported similar ADG with control on complete substitution of SBM with FDBM (11.5%). The author at the same time noted a tendency to decrease feed intake at these high levels of blood meal. It can therefore be concluded that levels of 11% FDBM have no effect on ADG unlike flash dried blood that depresses ADG at levels above 9%. Pigs on 11% FDBM however exhibited irregular feed intake that was not observed with other diets resulting in significantly lower feed intake than other diets.

King and Campbell (1978) reported significantly poorer FCR for diets with more than 75% flash dried blood meal substituting SBM. This is contrary to the results for FCR reported in this experiment where 90% substitution of SBM with FDBM had no effect on FCR. King'ori (1996) also reported similar FCR for control, 50% or 100% substitution of SBM with FDBM. King and Campbell (1978) attributed the poor FCR in their experiment to high lysine levels in the diet containing 11.8% blood meal. However blood meal used in this experiment was not exposed to heat hence there were no possibilities of heat damage. In situations of heat damage lysine is affected most. Therefore the lysine levels for blood meal used in this experiment could not have been lower than in flash dried blood meal. Therefore the diets formulated could have had lysine levels as high, if not higher, than in the diets used by King and Campbell (1978). It is therefore possible that factors other than high lysine content might have been responsible for low FCR in diets with 11.8% flash dried blood meal.

There were significant ($P<0.05$) sex differences on ADG and FI, but the efficiencies of feed utilisation were similar for both diets. This is contrary to results of experiment two where ADG and FI were similar for both sexes while the females were more efficient. Males ate more and grew faster than the females ($P<0.05$). Similar results have been obtained by Hahn et al. (1995) who reported faster ADG and FI for castrates than gilts. Under ad libitum intake barrows eat more feed than gilts or boars and therefore grow faster than either boars or gilts (Fuller, 1980). When allowed free access to feed, barrows have been reported to grow at 2.1% higher than boars (Kay and Houseman, 1974). The higher daily gain for barrows compared to females, due to their greater than females appetite, has also been reported by Baker et al. (1967), Davies (1974), Christian et al. (1980) and Cromwell (1993). At high protein levels, females and boars exhibit better FCR than castrates (Newman and Bowland, 1972; Fuller et al., 1976; Fuller, 1980; Hahn et al., 1995). Therefore it was expected that the females in this experiment would grow more efficiently than the castrates since the diets had higher CP (18%) than usual for growing pigs. However, the results obtained herein indicate similar efficiencies of feed utilisation for gilts and castrates (P>0.05). The reasons for similar FCR obtained in this study are not apparent. But Hahn et al. (1995) have suggested that the potential for daily gain for barrows relative to gilts could vary with genotype. The pigs used in this experiment were from the same herd hence similar genotype.

The results generally are in agreement with the observations by King and Campbell (1978) that more than 75% substitution of SBM with blood meal results in depression of FI. ADG and FCR are however not affected by addition of more than 75% FDBM contrary to the result of King and Campbell (1978) but in agreement with the results of King'ori (1996). Further research to compare nutritional quality of flash dried blood meal versus FDBM needs to be done to verify which is superior.

Regression analysis was carried out to determine a level of inclusion of FDBM that maximises FI, ADG and FCR. The aim was to find out at what level the ADG, FI, and G/F begins to decrease. The regression equations obtained are shown below;

General equation: $Y = a + \beta_1 X + \beta_2 X^2$

Where X = Level of fermented blood meal.

a = Y intercept

β = Regression coefficient

Specific equations;

ADG (kg)	$Y = 0.237 + 0.1205X - 0.0078X^2$, $R^2 = 0.0420$
FI (kg)	$Y = 0.428 + 0.275X - 0.0179X^2$, $R^2 = 0.0362$
FCE	$Y = 1.79 + 0.0886X - 0.0060X^2$, $R^2 = 0.0398$

On maximising the functions, the results indicated that the three factors were maximised at about 7% inclusion level. However the predictive abilities of the equations were very poor as reflected in the very low R^2 values. Therefore satisfactory regression equations which could tell the optimum level of inclusion were not obtained. It was therefore not possible to obtain optimum inclusion level for FDBM. More points covering a wider range of inclusion levels should have been included in the study.

CHAPTER FIVE

GENERAL DISCUSSION

This study set out to investigate the possibility of improving the fermentation process in preparing fermented blood meal, assess its nutritional value through a digestibility and nitrogen balance trial and finally confirm the appropriate substitution levels of SBM through a feeding trial.

In the fermentation experiment, the effect of various percentages of inoculant on the changes in pH of fresh blood-molasses mixture was evaluated. The results indicated a fast rate of pH drop to 4.2 in between 3 hours for 90% inoculant and 5 days for 60% inoculant. Therefore, inoculating the fresh blood-molasses mixture is a practical way of reducing the period required for complete fermentation to be achieved. The rapid fall in pH observed also indicates that fermentations done using inoculants may result in better preservation with lower final bacterial counts than the control. Erichsen (1983) reported that possibilities of contamination exist if microorganisms are allowed to multiply at the initial stages of fermentation. It is observed that in the first 24 hours there was a slight increase in pH in the control that is not observed in any of the inoculated samples. This slight rise in pH may allow a build up of bacteria to occur if the sample was originally contaminated. The results also indicate that farmers can use one or two fermentation containers to get a continuous supply of fermented blood meal depending on percentage inoculant used. More than 80% inoculant allows the blood meal to be used almost immediately while the rest takes between 3 and 5 days to be ready. The reduced fermentation period is important in that only small amounts of fresh blood may be available in a day and to have a continuous supply of fermented blood meal the farmer may have to collect blood almost on daily basis. Hence, it is instructive to know what period to wait before using it. Long storage of wet blood may not be feasible. Fermented foods should be kept under anaerobic conditions to prevent growth of yeast and moulds (Pederson, 1979; Lindgren and Pleje, 1983). Yeast inhibitors could be used to prevent growth of yeast that increase pH due to acid assimilation. Erichsen (1983) recommended refrigeration for fermented foods with more than 40% moisture content. Therefore where large quantities of fresh blood are available, problems of storage would still exist unless the FBM is dried immediately after fermentation. It may be of importance to investigate how long fermented wet blood meal will stay before spoilage under rural conditions without refrigeration or vacuum storage.

Drying is one of the operations involved in processing FBM. Its utility had not previously been ascertained. In this experiment, pigs fed diets with wet blood meal ate more feed and tended to grow faster than pigs on FDBM. The diet with the wet blood meal had higher moisture (26%) than the diet with dry blood meal (14%). Whether the differing moisture content was responsible for the difference in intake, was not possible to ascertain. However, Pond and Maner (1984) have reported conflicting results from experiments carried out using various ratios of feed to water. From the results obtained herein drying is an unnecessary expense which does not improve the utilization of FBM. Results of experiment 4 also show that FDBM and FWBM have similar NR and N digestibility. Since farmers usually do not mix feeds with water before availing them to the pigs, using wet blood meal in rations can be concluded to have advantages over use of dry FBM.

Proximate analysis of wastes can be most misleading and only actual digestibility and palatability data should be used to determine their worth (Wilson, 1980). In experiment 3 faecal digestibility values were measured. In a review on use of ileal digestibility values in ration formulation Tanksley and Knabe (1984) have reported consistently higher fecal digestibility values than ileal due to hydrolysis in the large intestines. The extent of hydrolysis varies with the level of fermentable materials reaching the large intestines (Misir and Sauer, 1982). This suggests that for diets with little fibre, ileal and fecal digestibility values are close. Tanksley and Knabe (1984) have stated that ileal values are of use in practical feed formulations only when unconventional feeds such as sunflower bran and cotton seed cake, which are high in CF, are used in rations. For blood meal, with practically no CF, fecal digestibility values can therefore be used in feed formulation. Digestibility of N and BV of a feed are only useful for comparative evaluation of feedstuffs (Bergner, 1996). From the results of experiment three, the three test diets have similar nitrogen digestibility and BV. Individual digestibilities of N in SBM, FDBM and FWBM are also similar. Using Bergner's (1996) conclusion on the usefulness of digestibility and BV, then substituting part of SBM for FWBM or FDBM does not affect the nitrogen utilization in the diets. The only factor affected is the overall DM digestibility that is lowered by substitution of SBM with FDBM or FWBM. Quiniou et al. (1995) have reported overestimation of NR values obtained if evaporative N loss is not taken into account. In this experiment the evaporative N loss was not considered. This suggests that the values reported could be overestimated by about 3% of N retained (Fernandez et. al., 1986). Fecal and urinary N losses can further increase the error on NR. Normally, after correction for gaseous losses, the balance technique for N determination is comparable to comparative slaughter technique method.

Use of by-products in place of conventional ingredients introduces nutritional changes to the diets which are ultimately reflected in the performance of the animals. The negative effects introduced by the by-products may erode the benefits accrued by use of the supposedly cheaper by-products. Hence it is worthwhile to ascertain the level of by-products in the diets which produce the best possible animal performance. Experiment 4 in this study set out to investigate the effect on performance of various substitution levels of SBM with FDBM. From the results, growing pigs, grow fastest and eat most when fed diets containing between 7% and 9% FDBM. 11% FDBM did not affect ADG and FE significantly although FI decreased. Also 10% FDBM in experiment three supported similar nitrogen balance with the control. This implies that FBM could be included in pig rations at upto 10-11%.

The results imply better nutritional value for FDBM than flash dried blood meal whose inclusion level is recommended at 6% (Walhstrom and Libal, 1977, King and Campbell, 1978). Spray dried porcine blood meal has also been reported to be superior to flash dried blood meal (Kats et al., 1994b). The same authors have also reported no difference between porcine and bovine spray dried blood meal. Therefore the only differences in nutritive values are due to processing methods rather than source of raw blood. Fermentation as a means of blood processing may therefore be superior to flash drying but it is not clear how it compares with spray dried blood meal. In experiment 2 females had a higher FCR than males but similar FI and ADG while in experiment 4 females had a lower ADG and FI but similar FCR to males. Both situations have been reported by other researchers (Fuller, 1980, Hahn et al., 1995). Hahn et al. (1995) have suggested that appetite or growth rate potential of barrows relative to gilts may be varying with genotype.

Practical Implications

It is recommended that blood be fermented using an inoculant to cut short the fermentation period. The initial sample from which the inoculants are to be obtained should be as free as possible of contaminants to avoid possibility of build up of contaminants in the initial stages of fermentation. For longer storage period, 40% inoculant or lower is advised since it is capable of achieving pH values lower than 4 which will provide even better storage potential.

FBM need not be dried before incorporating into rations for growing pigs. Using FBM in the wet form does not affect palatability of the ration. Its digestibility and apparent biological value are similar to FDBM. However mixing of rations using wet FBM is cumbersome. Shelf life of wet fermented blood meal is also not assured due to possible growth of moulds and yeast which destroy acidity with possible spoilage unless vacuum storage is assured.

SUMMARY AND CONCLUSIONS

1) Inoculating fresh blood-molasses mixture with a previous pre-fermented blood meal batch reduces the fermentation period to 5 days or less. A slight rise and the slow drop of pH was observed for the control but pH change for the

inoculated samples was very rapid. Using 40% or less inoculant resulted in a final pH lower than 4.0. It is concluded that the use of an inoculant is an effective way of reducing the period necessary to complete fermentation of blood meal.

2) Growing pigs on wet blood meal ate significantly more and tended to grow faster than those on dry blood meal. It is therefore concluded that drying FBM is not necessary before inclusion in growing pig rations. Using wet blood meal in rations could have advantages over dry blood meal due to increased intake and consequent growth rate observed.

3) Nitrogen digestibility, nitrogen retention and apparent biological value were similar for the three test diets. However dry matter digestibility was significantly depressed after substitution of SBM with FDBM or FWBM. Also nitrogen digestibility in FWBM and FDBM are similar. It is concluded that nitrogen utilization is not affected by substituting part of SBM in grower pig diets using FDBM or FWBM but DM digestibility is significantly depressed.

4) Upto 11% FDBM in grower pig diets did not affect ADG and FCR. 5% or 11% FDBM however depressed FI significantly. 7% and 9% inclusion levels in growing pig rations resulted in similar and significantly higher FI than 5% or 11% levels. It was not possible to establish the exact optimum inclusion level due to poor regression equations obtained.

REFERENCES

AOAC.1995. Official methods of analysis, Association of official analytical chemists. Arlington, VA.

ARC. 1981. The nutrient requirements of pigs. Common wealth agricultural Bureaux, Slough, UK.

Baker, D. H., C. E. Jordan, W. P. Waitt and D. G. Gouwens. 1967. Effect of a combination of diethyl stilbestrol and methyl testosterone, sex and dietary protein level on performance and carcass characteristics of finishing swine. J. Anim. Sci. 26:1059.

Batterham, E.S., 1992. Availability and utilisation of amino acids for growing pigs. Nutr. Research Reviews. 5:1

Batterham, E.S., R.F. Lower, R.E. Darnell, E.J. Major, 1986a. Availability of lysine in meat meal, meat and bone meal, and blood meal as determined by the slope-ratio assay with growing pigs, rats and chicks and by chemical techniques. Brit. J. Nutr. 55:427..

Batterham, E.S., R.E. Darnell, L.S. Herbert and E.J. Major, 1986b. Effect of pressure and temperature on availability of lysine in meat and bone meal as determined by slope ratio assays with growing pigs, rats, and chicks and by chemical techniques. Brit. J. Nutr. 55:441.

Becker, D. E., I. D. Smith, S. W. Terrill, A. H. Jensen and H.W. Norton. 1963. Isoleusine need of swine at two stages of development. J. Anim. Sci. 22:1093.

Berger, J.C.A., J.P. Fontenot, E.T. Kornergoy and K.E. Webb, Jr., 1981 a. Feeding swine wastes. Fermentation characteristics of swine waste ensiled with ground hay or ground corn grain. J. Anim. Sci. 52:1388.

Berger, J.C.A., E.T. Kornergay, J.P. Fontenot and K.E. Webb. Jr., 1981 b. Feeding swine waste III.. Digestibility, nitrogen utilisation and palatability of ensiled swine waste and corn grain or orchard grass hay fed to swine. J. Anim. Sci. 52:1406

Bergner, A., 1995. Estimation of protein quality of foods and feedsuffs - an overview. Anim. Res. and Dev. 42:42.

Carr, J.R.,K.N. Boorman and D.J.A. Cole. 1977. Nitrogen retention in the pig. Br. J. Nutr. 37: 143.

Caswell, L.F., J.P. Fontenot and K.E. Webb, Jr., 1978. Fermentation and utilisation of broiler litter ensiled at different moisture levels. J. Animal. Sci. 46:547.

Caswell, L.F., K.E. Webb, Jr. and J.P. Fontenot, 1977. Fermentation, nitrogen utilisation, palatability of broiler litter ensiled with high moisture corn grain. J. Anim. Sci. 44:803.

CBS, 1995 a. Central Bureae of statistics, Office of the vice-president and Ministry of Planning and National Development, Control Bureau of Statistics, 1995. Economic survey.

CBS, 1995 b. Central Bureau of Statistics, Office of the vice-president and Ministry of Planning and National development, 1995. Statistical abstract. pp. 129.

Cheeke, P.R., 1991. Applied Animal Nutrition: Feeds and Feeding. Macmillan Publishing Company, New York. 88. pp.

Christian, L. L., K. L. Strock, and J. P. Carlson. 1980. Effects of protein, breed ,cross sex and slaughter weight on swine performance and carcass traits. J. Anim. Sci. 51:51.

Cook, E. M. and H. D. Dumont. 1991. Process of drying practice. McGraw publishing Co., Newyork.

Cooke, B.C. and M.Z. Pugh., 1980. Slaughter wastes in animal feeding. In: By-products and wastes in animal feeding, occasional publication No 3. British society of animal production (E.R Orskov, Ed), 1980.

Cornman, A.W., W.D. Lamm, K.E. Webb, Jr. and J.P Fontenot., 1981. Ensiling cattle waste with rye straw as a diet supplement for ruminants. J. Anim. Sci. 52:1233.

Cromwell, G.L., T. R. Cline, J. D. Crenshow, T. D. Crenshaw, R. C. Ewan, C. R. Halmilton, A. J. Lewis , D. C. Mahan, E. R. Miller, J. E. Pettigrew, L. F. Tribble, and T. L. Veum, 1993. (NCR-42 Committee on swine nutrition). The dietary protein and/or lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510.

Davies, A.S., 1974. Effect of sex and genotype on growth. Anim. Prod. 19:367.

Divakaran S. 1987. An invitro quality evaluation of slaughter house by-products preserved by pickling with sulphuric acid. Biological wastes, 19: 281.

Divakaran, S. and T. R. Sawa. 1986. Characteristics of slaughter house by-products preserved by pickling with inorganic acids. Biological wastes. 17:67.

Erichsen I., 1983. Fermented fish and meat products: The present position and future possibilities. In: Food microbiology; Advances and Prospects. 1983

(T.A. Roberts and T.A. Skinner, Editors): Academic press, inc. London. pp. 271.

Falcon, W. P., C. t. Korien, F. Monckeberg, A. P. Okeyo, S. O. Olayide, F. Rabar, W. Tims, 1987. The world food and hunger problem;Changing perspectives and possibilities, 1974 - 84 In: Price Gittinger, J. J. Leslie and C. Haisington (Eds); Food policy. Integrating supply, distribution and consumption. Baltimore, MD, USA, John hopkins univ. press, 1987. pp. 15.

FAO, 1982. The state of food and agriculture. FAO agriculture series. No. 15. Rome.

FAO, 1992. The state of food and agriculture. FAO food series No. 25. Rome.

FAO, 1994 The state of food and agriculture. FAO agriculture series. No. 27. Rome.

Fernandez, J.A., H. Jorgensen and A. Just., 1986. Comparative digestibility experiment with growing pigs and adult sows. Anim. Prod. 43:127.

Franzen, H., M. Reule, J. Richter, K.J. Peters and C. Gall., 1996. Is animal farming in developing countries still worth financing. Anim. Res. and Dev. 43/44:17.

Fuller, M.F., 1980. Sex differences in nutrition and growth of pigs. In: Recent advances in animal nutrition (Haresign W. D. Lewis Eds.). Butterworths, London. pp. 157.

Fuller, M.F., P.R. English, R.M. Livingstone and R.M.J. Crofts., 1976. Effect of simultaneous reduction of food intakes and dietary protein concentration on the growth and carcass quality of bacon pigs. J. Agri. Sci. Camb. 86: 7.

Gould, G.W., M.H. Brown and B.C. Fletcher, 1983. Food preservation procedures. In: Food microbiology: Advances and prospects., 1983. (T.A. Roberts and F.A. Skinner, Editors). Academic press, inc. London. pp. 271.

Government printers.The sixth national development plan. 1987-1993, Nairobi.

Hahn, J.D., R.R. Biehl, and D.H. Baker, 1995. Ideal digestible lysine level for early and late-finishing swine. J. Anim. Sci. 73:773.

Hamm, D. and G.K. Searcy., 1976. Some factors which affect the availability of lysine in blood meals. Poultry Sci. 55:582.

Hansen, J.A., J.L. Nelssen, R.D. Goodsand and T.L. Weeden., 1993. Evaluation of animal protein supplement in diets of early weaned pigs. J. Anim. Sci. 71:1853.

Harmon, B. W., J. P. Fontenot and K. E. Webb, Jr. 1975. Ensiled Broiler litter and corn forage. 1. Fermentation characteristics. J. anim. sci. 40:144

Herkelman, K.L., G.L. Cromwell, T.S. Stahly, T.W. Pfeiffer, and D.A. Knabe., 1992. Apparent digestibility of amino acids in raw and heated conventional and low-trypsine-inhibitor soybeans for pigs. J. Anim. Sci. 70:818.

Herkelman, K.L., S.L. Rodhouse, T.L. Veum. and Mr. Ellersieck., 1990. Effect of extrusion on ileal and faecal digestibilities of lysine in yellow corn in diets for young pigs. J. Anim. Sci. 68:2414.

Holness, D.H. (ed.). The tropical agriculturalist. Macmillan. 1996. pp. 16.

Howell, M.V., 1982. Moulds and mycotoxins in animal feedstuffs. Recent advances in animal nutrition (W. Haresign, Ed.). Butterworths, London. pp.3.

Jacob, J.P., 1993. The feeding value of Kenyan Sorghum, Sunflower seed cake and Sesame seed cake for poultry. Ph.D. Thesis. The university of British Columbia.

Kats, L.J., Nelssen, M.D., Tokach, R.D Goodband, J.A. Hansen and J.L. Laurin., 1994a. The effect of spray-dried porcine plasma on growth performance in the early weaned pig. J. Anim. Sci. 72:275.

Kats, L.J., J.L. Nelssen, M.D. Tokach, R.D. Goodband, T.L. Weeden, S.S. Dritz, J.A. Hansen and K.G. Friesen., 1994b. The effect of spray dried blood meal on growth performance of the early weaned pig. J. Anim. Sci. 72:2860.

Kay, M. and R. Houseman., 1974. The influence of sex on meat production. In: Meat, 1974 (D.J.A. Cole and R.A. Laurin, Editors) Nottingham. Butterworths. pp. 85.

Kays, J.K. and J.V. Debarthe., 1974. Site and extent of carbohydrates, dry matter, energy and protein digestion and the rate of passage of grain diets in swine. J. Anim. Sci. 39:57.

Kenya population census . 1989. Analytical report. Vol. 7. April, 1996.

King, R.H. and R.G. Campbell. 1978. Blood meal as a source of protein for grower/finisher pigs. Anim. Feed Sci. and Technol. 3:191

Kingo'ri, A. M. 1996. Comparison of two processing methods of blood as a protein supplement for growing pigs. M.sc. Thesis. Egerton University.

Lin, F.D., D.A. Knabe, T.D. Tankslay, Jr., 1987. Apparent digestibility of amino acids, gross energy and starch in corn, sorghum, wheat, barley, oat groats and wheat mindlings for growing pigs. J. Anim. Sci. 64:1655.

Lindgren, S. and Pleje, M., 1983. Silage fermentation of fish or fish waste products with lactic acid bacteria. J. Sci. Food and Agric. 34-1057.

Livestock project appraisal report. 1992. Ministry of agriculture Livestock Development and Marketing, Ref: No: Ken/PAAL/92/01. A report sponsored by African Development Fund, 1992. pp. 13.

Livingstone, R. M. 1981. Associative effects of feeds on digestive efficiency in the small intestines of pigs. Anim. Prod. 32:396

Maurine, J., 1981. The maillard reaction in food: A critical review from the nutritional standpoint. Prog. Fd. Nutr. Sci. No.5 pp. 5.

McCaskey, T.A. and W.B. Anthony., 1975. Health aspects of feeding animal wastes conserved in silage. Proc. international symp. on livestock wastes. ASAE Pub. Proc. 275:230.

Miller, E.R. and M.J. Parsons., 1982. Flash dried blood meal as an ingredient for pig diets. Nutr. Abstr. Reviews. 52:447.

Miller, E.R., M.J. Parsons, P.K. Ku., W.G. Bergen, and D.E. Ullrey. 1977. Bio-availability of lysine in ring process dried cattle blood versus swine blood. J. Anim. Sci. 42:1356 (Abstr.)

Misir, R. and W.C. Sauer., 1982. Effect of starch infusion at the terminal ileum on nitrogen balance and apparent digestibilities of nitrogen and amino acids in pigs fed meat and bone and soybean meat diets. J. Anim. Sci. 55:599.

MOALD and M, 1994. Ministry of agriculture Livestock Development and Marketing., 1994. Annual report. pp. 76.

Muller, H.G. (Ed.). An introduction to tropical food science, Cambridge university press. Cambridge. 1988. pp. 92.

Naegel, L.C.A., 1996. Development of small scale sustainable farming systems in non-industrialised countries. New concepts are needed. Anim. Res. Dev. 43/44. pp 25.

Neidhardt, R., H. Gnell, W. Schreske and H. Jakots 1996. Sustainable livestock farming in East Africa. Anim. Res. Dev. 43/44. pp 44.

Nelson, T.S. and L.K. Kirby., 1982. Content and digestibility by chicks of the amino acids in feed ingredients. Nutri. Abstr. Reviews. 52:779.

NRC. 1988. Nutrient requirements for domestic animals No. 2. Nutrient requirements for swine, 9th edition. National acedamy of science. Washington, DC: National cademy Press.

Owen, K.Q., J.L. Nelssen, M.D. Tokach, R.D. Goodband, L.J. Kats, K.G. Friesen, B.T. Richert, and R.E. Musser., 1993. The effect of increasing dietary methionine in the phase II starter pig diets. J. Anim. Sci. 71:176 (Abstr.)

Owen, K.Q., J.L. Nelssen, R. D. Goodband, M.D. Tokach, L.J. Kats, and K.G. Friesen, 1995. Added dietary methionine in starter pig diets containing spray dried blood products. J. Anim. Sci. 73:2647.

Parsons, M.J., E.R. Miller, W.C. Bergen, P.K. Ku, F.F. Green and D.E. Ullrey. 1975. Bioavaillability of lysine in blood meal for swine. J. Anim. sci. 42: 325

Pederson, C.S. 1996 (Ed.). Microbiology of food fermentation. Avi publishing Co., Inc. West-port, Conn., 1971. 74.

Pond, W.G. and J.H. Maner. 1984. Swine production and nutrition. West port. Avi publishing co.

Quiniou, N., J.Y. Dourmad and J. Noblet., 1996. Effect of energy intake on the performance of different types of pigs from 45 to 100 kg body weight. I. protein and lipid deposition. Anim Sci. 63:277.

Quiniou, N., S. Dubois, J., J. Noblet., 1995. Effect of dietary crude protein level on protein and energy balances in growing pigs. Comparison of two measurement methods. Livest. Prod. Sci. 41:51.

Raymond, W.F., 1980. Perspectives of animal nutrition with efficient use of by-products and wastes. In: (DR. E.R. Oskov Ed.) by-products and wastes in animal feeding occasional publication No. 3. pp.13.

SAS., 1987. SAS users guide. Statistics. SAS. Inst., Inc., Cary, NC.

Schneider, B.H. and W.P. Flatt., 1975. The evaluation of feeds through digestibility experiment. University of Georgia, USA pp. 143.

Seerley, R.W., D. Burdick, W.C, Russom, R.S, Lawrey, H. C. McCampbell and H.E. Amos. 1974. Sunflower meal as a replacement for soybean meal in growing swine and rat diets. J. Anim. Sci. 40: 947

Shahani, K.M. and R.C. Chandan., 1979. Nutritional and healthful aspects of cultured and culture containing dairy foods. J. Dairy Sci. 62:1685.

Simhaee, E. and K. Keshavanz., 1974. Comparison of gross protein value and metabolizable energy of dried skim milk and dried yoghurt. Poultry Sci. 53:184.

Smulders, F.J.M., 1986. Prospectives for microbial decontamination of meat and poultry by organic acids with special reference to lactic acid. In: (F. M. Smulders, Ed.) Elimination of pathogenic organisms from meat and poultry. 1986. Elsevier. pp. 319.

Sohn, K.S., C.V. Maxwell, and D.S. Buchanan. 1991. Plasma protein as an alternative protein source for early weaned pigs. J. Anim. Sci. 69 (suppl.1): 362 (abstr.)

Stamer, J.R., 1988. Lactic acid bacteria in fermented vegetables. In:(K.R. Robinson, Ed.) Developments in food microbiology - 3. 1988. Elsevier Science publishing Co., New York. pp. 67.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics (2nd ed.) Mcgraw-Hill Book Co., Inc.., New York.

Strumillo, C. and T. Kudra.1986. Drying: Principles, applications and design. Gordon and breach science publishers, New York.

Sullivan, J.S., D.A. Knabe, A.J. Bockolt and E.J. Gregg., 1989. Nutritional value of quality protein maize and food corn for starter and grower pigs. J. Anim. Sci. 67:1285.

Tanksley, T.D. Jr. and D.A. Knabe., 1984. Ileal digestibility of amino acids in pig feeds and their use in formulating diets. In: (B. W. Haresign and D.J.A. Cole. Editors) Recent Advances in Animal Nutrition, 1984: pp. 75, London; Butterworths.

Tuitoek, J.K. 1994. The supplementation of low protein pig diets with limiting amino acids according to the ileal digestible ideal amino acid pattern. P. hD. Thesis. University of Guelph, Ontario, Canada.

Tuitoek, J.K., 1984. A general out look of Kenya's pig industry with special reference to the past. A paper presented at a seminar held at N.A. H.R.S. 7th Feb., 1984.

Tuitoek, J.K., and A.O. Ayangbile., 1992. Fermented cattle blood for growing pigs. Bull. Anim. Prod. Hlth. Afri. 40:293.

USDA, 1991: World livestock situation. World watch. Bericht des world watch institute. Library of congress.

VOPS, 1988. Vegetable oil/protein system project. Poultry industry in relation to oil seed cake utilization in Kenya (Gichohi C.M. Ed.). Working paper No. 7a. Egerton University, Kenya.

Wahlstrom, R.C. and G.W. Libal., 1977. Dried blood meal as a protein source in diets for growing-finishing swine. J. Anim. Sci. 44:778.

Waibel, P.E., M. Cuperlovic, R.F. Hurnell, and K.J. Carpenter, 1977. Processing damage to lysine and other amino acids in the manufacture of blood meal. J. Agric. Food. Chem. 25:171.

Walker, M., 1977. The composition of processed abattoir blood and its use in finishing pig diets. Anim. Feed. Sci. Technol. 2:21.

Watanabe, M., 1982. Turning kitchen waste into feed with the help of lactic acid bacteria. Nutr. Abstr. Rev. 1983. 53:317.

Wetch, J.G., R.H. Cordts, and G.W. Vandernoot, 1964. Swine metabolism unit for 100 to 200 pound barrows. J. Anim. Sci. 23:183.

Williamson - Gardner, A. 1971. Industrial drying. Leonard Hill Books, London.

Wilson, P.N., 1980. The use of By-products in animal feeds. In: (E.R. Orskov, Ed.) By-products and wastes in animal feeding. An occasional publication No. 3 of British Society of Anim. Prod. 1980. pp. 113.