EFFECTS OF FEEDING BREWERS' SPENT GRAINS ON THE PERFORMANCE OF GROWING PIGS IN RWANDA

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A thesis submitted to the Graduate School in Partial fulfilment for the requirements of award of Master of Science Degree in Animal Nutrition of Egerton University

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DECLARATION AND RECOMMENDATION

DECLARATION

I hereby declare that this thesis is my original work and has not been presented in any other University for the award of degree.

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RECOMMENDATION

This thesis has been submitted with our approval as supervisors for examination according to Egerton University regulations.

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DEDICATION

First and foremost, this work is dedicated to the Almighty God for his guidance and protection during my studies. I also dedicate this work to my family, my husband Sendashonga Claude and my son Hirwa Ethan Sendex for their prayers and support.

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ABSTRACT

Livestock production is one of the major sources of income in Rwanda. Pigs are among preferred livestock due to their short generation interval and small space requirement. Feeds account for 65-70% of total production costs in pig rearing, which invariably affects profit margins. Therefore search for alternative feedstuffs that are locally available and affordable like brewers' spent grains (BSG) can be used to feed pigs and reduce the cost of production. BSG is the first solid material by-product that remains after barley grain has been fermented during the beer making process. This study evaluated the nutrient composition, effect and economics of substituting sow and weaner meal (SWM) with BSG on the performance of growing pigs in Rwanda. A feeding trial was conducted using 30 gilts of Landrace x Pietrain cross weighing 30 - 40±5kg. A completely randomized design (CRD) was used in which pigs were randomly allocated to 10 pens based on initial weight with 3 pigs per pen. Five treatments of BSG replacing SWM at a rate of 0% (T1), 25% (T2), 50% (T3), 75% (T4) and 100% (T5) were randomly assigned to pigs for 42 days. Weekly data on average daily feed intake (ADFI), average daily gain (ADG), feed conversion ratio (FCR) and net returns (based on the variable costs of production) was collected. Proximate analysis showed that nutrient composition of BSG and SWM differed significantly ($P<0.05$). BSG was higher in crude protein (CP) and crude fibre (CF) but lower in metabolizable energy (ME) compared to SWM. ADFI significantly increased from T1 to T3 and then decreased to T5 ($P<0.05$). Diet T3 had higher ADFI (4.14kg/pig/day) compared to T1 (2.31kg/pig/day) probably due to the high moisture content of BSG. The ADG was significantly different ($P<0.05$) among diets, but T1-T3 were similar ($P>0.05$) whereas T2 had higher ADG. Diet T5 resulted in loss of body weight of -0.153kg/pig/day probably due to the high CF and low dry matter in BSG. FCR was not different ($P>0.05$) in T1-T3 but significantly ($P<0.05$) different in T4 and T5. Feed cost decreased with the increase in BSG levels. The net return was higher in T3 (50% BSG) and lowest in T5. Based on the results of this study, it can be concluded that BSG can replace up to 50% SWM in grower pigs' diets without adverse effect on daily gain and with some savings in feed costs.

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LIST OF ABBREVIATIONS

ADG	Average daily gain
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
BSG	Brewers' spent grains
BDG	Brewers' dried grains
BW	Brewers' waste
CF	Crude fibre
CP	Crude protein
DCP	Dicalcium phosphate
DF	Dietary fibre
DM	Dry matter
FAO	Food and Agriculture Organization
FCR	Feed convention ratio
GDP	Gross domestic product
GLM	General linear model
ISAR	Institut des Sciences Agronomiques du Rwanda
KES	Kenya shilling
Ltd	Limited
ME	Metabolizable energy
MINAGRI	Ministry of Agriculture and Animal Resources
NISR	National Institute of Statistics of Rwanda
RFW	Rwandan francs
SAS	Statistical analysis systems
TDN	Total digestible nutrients
WBW	Wet brewers' waste

CHAPTER ONE

1. INTRODUCTION

1.1 Background information

Livestock production is among the major sources of income for the national economy and food security for resource-poor households and contributes about 40% globally to the agricultural GDP. In the developing countries it contributes 30% of the agricultural GDP (World Bank, 2009). In Rwanda, livestock accounts 12% of GDP and 30% of agricultural GDP (MINAGRI, 2012a). The current livestock population in Rwanda is poultry (4.081 million), goats (2.971 million), cattle (1.335 million), rabbits (0.845 million), sheep (0.799 million), and pigs (0.706 million). Livestock population is on an increasing trend with growth rates for the period 2005-2010 of: 97.8% rabbits, 93% poultry, 78.5% goats, 35.4% pigs, 23.9% cattle and 15.8% sheep (MINAGRI, 2012a). The government has imported pigs from Uganda which have been distributed among the various districts where pig farming is popular. Belgian Landrace, Large White and Pietrain are the breeds in the semi-commercial pig stock in Rwanda (MINAGRI, 2012b). Livestock sub-sector in Rwanda contributes significantly to the national economy and its potential has been limited by several constraints such as the use of animals with poor genetic potential, inadequate feeding, pests and diseases and poor management (MINAGRI, 2012b).

Pigs are preferred because of their advantages such as high potential for socio-economic and high return to investments, high fecundity rate and high feed conversion efficiency, early maturity, short generation interval (high production return), relatively small space requirement and ability to produce maximally under varied management systems (Lekule and Kyvsgaard, 2003; Ajala, 2003). The major constraints are related to poor nutrition, animal health, animal productivity/genetic makeup, extension services, provision of finance to small-scale producers and marketing (Huynh *et al.*, 2007). The cost of producing livestock, especially non-ruminants, has become high mainly due to the high cost of conventional feed ingredients which are mostly imported and competition with humans for feeds like staple grains and oilseeds (Rijal *et al.*, 2009).

Okai *et al.* (2001) and Rijal *et al*. (2009) indicated that, the major cost item in producing monogastric farm animals like pigs is feed which ranges between 60 and 70% of the total operating cost. Alternative feedstuffs that may be locally available and affordable can fill the need created by the current increase of commercial feed prices (Okai *et al*., 2013). Therefore, any attempt to improve commercial swine production and increase its efficiency, needs to focus on better utilization of available feed resources (Cline and Richert, 2001). These by-products include brewers' spent grains, cassava leaves, banana peels, sugar beet and citrus pulp, wheat bran and distiller's soluble (Rhule *et al*., 2007).

Brewers' spent grains (BSGs) are the first solid material that remains after grains have been fermented during beer making process. BSG is the most abundant brewing by-product, comprising of 85% of by-products generated from the industry, 31% of original malt weight and 20 kilograms per 100 litres of beer produced (Gupta *et al*., 2010). At present, the use of BSG as a feedstock is limited, primarily as animal feeds (Gupta *et al*., 2010). BSG is a relatively good source of protein and has been used in feeding pigs, sheep, poultry and cattle (Westendorf and Wohlt, 2002). BSG of barley malt, corn or rice is treated to remove most of the readily soluble carbohydrates and is high in protein, fibre, linoleic fatty acid, B-vitamins and phosphorus but low in other minerals (Shurson, 2003).

Brewery grains are available in large quantity of the local brewery industries, which can be a potential feed ingredient to economize pig production (Robertson *et al*., 2010). BSG is a cheaper and less competitive source of livestock feed and some has been reported to play an important role in the maintenance of normal structure and function of intestinal mucosa because of the high fibre content (Adesehinwa, 2007). Livestock, especially pigs, are prolific and fast growing animals that can convert food waste to valuable products. BSG can be fed to pigs, with high quality of the protein. This makes it more suitable for pigs with low energy requirements such as gestating sows and boars, rather than to growing pigs and lactating sows, particularly in intensive production systems (Blair, 2007; Boessinger *et al*., 2005). Pigs are less able to utilize high crude fibre than other livestock like cattle; but a fully grown pig can conveniently handle 3–5 kg of leafy succulent green feeds (Ranjhan, 1990). Therefore, there is a need to determine the nutrient composition and to evaluate the performance of growing pigs fed on different inclusion levels of BSG diets and the economics of feeding these diets in Rwanda.

1.2 Statement of the problem

Since feed cost constitutes 65-70% of total cost of production, therefore any reduction in the feeding cost may lead to a reduction in the total production cost (Rijal *et al*., 2009). This has led to the search for alternative locally available and affordable feed resources for compounding livestock feeds. BSG in Rwanda has been identified as a feed resource with potential for use in pig feed formulation. BSG has high nutritive value of CP value of 21-29% (Westendrof and Wohlt, 2002), a moisture content of 70-75% in wet or 10-12% in the dry form. The high CP content of BSG can help to replace the cost of expensive protein source of conventional feedstuffs. Above 10% moisture in BSG, spoilage is high due to mould growth (Tang *et al.,* 2005) as well as storage and this is a limiting factor of its use by farmers. The impact on relatively high dietary fibre levels (>20) in the diet of gut environment and digestibility may differ with fibre properties (soluble vs. insoluble) and with age (Högberg *et al*., 2006). The positive effects of increasing the dietary fibre content of a diet are argued to maintain and support normal physiological gastrointestinal (GI) function and gut health (Wenk, 2001). Growing pigs can handle up to 6% level of dietary crude fibre (Mateos *et al*., (2006). However, a too high level of dietary fibre (>6%) in the diet can be harmful and could cause an unbalanced gastro-intestinal (GI) functions as well as decreased digestibility and energy value of the diet (Le Goff *et al*., 2002; Wilfart *et al*., 2007). The nutritive value of BSG as a feed resource for growing pigs and effect of different inclusion levels in pig diets has not been evaluated in Rwanda.

1.3 Objectives

1.3.1 Broad objective

To contribute to sustainable pig production through use of brewers' spent grains (BSG) as a substitute for sow and weaner meal (SWM) for growing pigs in Rwanda.

1.3.2 Specific objectives

1. To determine the nutrient composition of BSG commonly found in Rwanda.
2. To evaluate the effects of substituting BSG for SWM at different inclusion levels on the performance (feed intake, average daily gain and feed conversion ratio) of growing pigs.
3. To analyse the cost benefits of substituting BSG for SWM as a feed for growing pigs.

1.4 Hypotheses

1. Ho: The nutrient composition of BSG from the breweries in Rwanda is not different and is similar to that of SWM used in Rwanda.
2. Ho: The performance (feed intake, average daily gain and feed conversion ratio) of growing pigs fed a diet with different inclusion levels of BSG is similar to that of pigs fed on SWM alone.
3. Ho: The cost benefits of substituting SMW with BSG as feed for growing pigs is similar to that of pigs fed on SWM alone.

1.5 Justification

Due to the effects of climate change, diversion of maize grain for production of biofuel (methanol) and the challenge of maize necrotic disease, there is need to explore alternative feed resources for monogastric. Efforts have been made to optimize feed efficiency so that feed costs might be reduced by using brewers' spent grains (BSG). BSG, a major by-product from the brewing industry is one such alternative. BSG is locally available and affordable in Rwanda compared to SWM and can replace SWM in growing pig diets. This study determined the effects of using BSG at different inclusion levels on the performance of growing pigs and also the economic advantage of using BSG as a feed for pigs.

1.6 The scope and limitations of the study

The major challenge faced in this study was that pigs were previously used to being fed on feed mixed with water, so adaptation of feeding a mixture of water and feed separately took time. Besides that, the season affected feed preparation. Initially experimental diets were to be formulated using BSG in the dried form. However, February was a very rainy period in Rwanda, which proved a challenge to have it dried, hence it was used in the wet form. Using wet BSG posed a challenge especially in storage and during feed preparation (mixing) due to the high moisture content. This meant that only small amounts of feed had to be prepared on a daily basis.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Background information

The cost of producing livestock, especially non-ruminants, has become high mainly due to the cost of conventional feed ingredients that are mostly imported. Feed costs and competition with humans for feed ingredients suggests strongly that alternative sources should be sought. Crop residues and industrial by-products can partially or wholly replace maize in livestock diets. This will reduce cost of meat production and make available the major cereal crops for human consumption. Okai *et al*. (2001) indicated that, the major cost item in producing monogastric animal like pigs are feeds cost. It has been established that the high cost of conventional feed ingredients is partly due to their high demand which has arisen from the competition between humans, industries and animals (Ani *et al.,* 2013). Furthermore, the increase in demand for grains as raw materials in biofuel production (Von Braun, 2007) has led to unprecedented rates of increase in prices of grains and threatened the use of grains of livestock enterprises. For these reasons, nutritionists have channelled their efforts into finding cheaper alternatives to conventional feed ingredients (Okai *et al*., 2013).

2.2 The potential of pig production in developing countries

When compared cattle, to other ruminants, pigs have some major potential advantages, namely:

a) They produce meat without contributing to the deterioration of the natural grazing lands. This is of paramount importance in relation to the current steady rate of desertification, soil erosion and loss of productive land in tropical and sub-tropical parts of the world (Mpofu and Makuza, 2003).

b) They convert concentrated food to meat, twice as efficiently as ruminants (high feed conversion efficiency) (Osaro, 1995; Karol and Krider, 2001).

c) If confined, maximum use can be made of their manure and effluent.

d) Their relatively small size when compared with cattle provide for more flexibility in marketing and consumption.

e) They possess the potential to be highly productive because they are capable of producing large litters after a relatively short gestation period (114 days), and have a short generation interval than cattle and grow rapidly. The pig's output (yield of meat/tonne of live weight of breeding females per year) are 6 times that of cattle (Mpofu and Makuza, 2003; Holness, 2007).

f) The meat from pigs are particularly suitable for processing into a variety products. Pigs are known for their meat yield, which in terms of dressing percentage ranges from 65-80% in comparison to other livestock species whose dressing yields may not exceed 65%.

2.3 Pig production in Rwanda

Rwanda is an agricultural country where urban and peri-urban livestock production is a very important source of income and a number of people have been engaged in small livestock production in the past 10 years (Nyiransengimana and Mbarubukeye, 2005). In African countries with pig production, missionaries played an important role in the introduction of European pig breed (MINAGRI, 2012b). The government of Rwanda has imported pigs from Uganda and have been distributed to the various districts where people keep pigs. The Belgian Landrace, Large White and Pietrain are the common breeds used in the semi-commercial pig stock in the country (MINAGRI, 2012b).

The major challenges in the Rwandan pig sector are proper feeding with available resources and selection of genetic material for improvement, considering the strong genotype-environmental interactions existing between husbandry or feeding and production. There are 2 categories of pig farmers in Rwanda such as: Small-scale village pig production and semi intensive pig production. The small scale village production system uses indigenous pig stocks (local breed; black, spotted), feeding on crop residues and kitchen waste. The semi-intensive production system uses exotic breeds and crosses which are fed on commercial feeds or a combination of commercial feeds, crop residues and kitchen waste. In a small scale production, piglets are sold to other farmers with capacity for fattening or are fattened on a farm if there are enough fed resources (MINAGRI, 2012b).

The meat per capita consumption of Rwandans is very low (10 kg per year) as compared to the African average (32 Kg per year). The reasons could be due to the purchasing power of the people, the eating habits like food taboos related to consumptions of mutton and rabbit meat and the access to quality meat, particularly for rural people (MINAGRI, 2012a). There is only one private pig slaughter facility in the country (Rulindo District) and the meat is sold fresh. In Kigali there are 3 main buyers of carcasses and sellers of pork and pork products (German Butchery, Kigali Boucherie Charcuterie and Simba Supermarket) having processing facilities (MINAGRI, 2012a).

2.3.1 Constraints to pig production

There are some identified problems facing livestock production which includes weather fluctuation, poor vegetation growth, diseases and parasites, religious beliefs, illiteracy leading to poor skills, poverty and shortage of animal feeds (Adesehinwa *et al*., 2003). Holnes (2007) enumerated some of the constraints on pig production as follows:

1. There are religious and social constraints because Moslems and believers in Jewish faith are forbidden from producing and eating pig meat (pork).
2. As simple-stomached animals, they may compete with human beings for food.
3. Pigs are not used as draught animals.
4. Their faeces and effluents cause environmental pollution if not properly handled.
5. As co-hosts of man to a number of parasites, pigs not confined can spread these parasites to man (Serres, 1999).

Farm animals require optimum temperature and clement weather condition coupled with good management, in order to attain the highest productive capacity. In line with this, any condition below this result from of low profitability. For instance, pigs are highly sensitive to temperature changes especially during hot weather condition due to heavy fat deposit in their body tissues. Generally, pigs require cool weather condition and this is the main reason why they are usually provided with wallowing in hot weather condition to buffer the effect of hot environment (Serres, 1999). Insufficient nutritious feeds are great problem of animal production especially in piggeries. Feeds are needed from both organic and inorganic sources (Sundrum, *et al*., 2007). The production performance of pigs depends on sufficient right type of feeds, increase of nutrient digestibility and feed conversion efficiency (John, 2011). However, recently in organic pig production, foraging is now receiving great attention due to its high nutritive value (Sundrum, *et al*., 2007). In terms of conventional feeds, pig feeds account for the greater percentage of the total pig production costs (Holness, 2007).

2.4 Management and health of pigs

In view of the fact that over-crowding leads to reduced performance of pigs of various categories, there should be proper spacing for different types of pigs at different stages of growth (Osaro, 1995). Collective pens must allow $1m^2$ per pig between 20 kg and 50 kg, $2m^2$ between 50kg and 100kg and $2.5m^2$ for dry sows, therefore a pen with dimensions 4m x 5m may house 20 piglets, 10 fattening pigs, 8 sows, 1 boar while 1 lactating sow and litter must have at least $10m^2$. In feeding the pigs, farmers should be guided by the following principles as recommended by Serres (1999).

The management practices if carefully followed, will minimize the occurrence of diseases. Prevention is better than cure is very relevant in the pig industry. A clean, sanitary environment provides the best prevention of internal and external parasites which can be serious problems. Anthelmintic and other drugs, when properly used, aid in the elimination of parasites. They can also promote growth in pigs when given at recommended levels. For diseases that can be prevented through vaccination, veterinarians should be contacted to provide such services routinely. A basic knowledge of the main diseases which may affect a pig herd is necessary so that a producer can diagnose the condition and implement control measures as quickly, as possible (Ikani and Dafwang, 1976).

2.4.1 Nutrient requirements of pigs

In the absence of feed, the nutrients required for supporting maintenance activities must come from the breakdown of body tissues and leads to loss of weight in the animal. Pigs thrive under less than optimal conditions, but just like all other animals, they require adequate and balanced diets, good management including housing and adequate veterinary care. The use of improved feeds and management practices and disease control measures are important factors in developing pig industry (Koney, 2004). Locally available feeds and available feed additives or supplements judiciously in order to maintain the required nutrients. These principles, if followed, will reduce cost of production and the additives will help increase nutrient digestibility, palatability, feed utilization, nutrient release and reduced excretion of unutilized nutrients, higher body immunity, higher yield and excellent profitability (Koeleman, 2005).

The farmer must carefully consider the economic benefits of using one feedstuff or the other before using them (Adesehinwa, 2007). Pigs at different stages of growth require nutrients (Table 1) for various reasons to support their lives, such as; replacement of worn out tissues in mature animals and building of new tissues in young and maintenance of essential body processes such as respiration, circulation and manufacture of internal secretion(s) (Adebambo, 1995).

Table 1. Nutrient requirements of growing-finishing pigs fed *ad libitum*, amount/kg diet (90% DM)

	Live weight (kg)		
Nutrient	10-20	20-50	50-100
DE (MJ/day)	14.2	14.2	14.2
ME (MJ/kg)	13.7	13.7	13.7
CP (g/kg)	209	180	155
Amino acids (g/kg)			
Arginine	4.6	3.7	2.7
Isoleucine	6.3	5.1	4.2
Leucine	11.2	9.0	7.1
Lysine	11.5	9.5	7.5
Methionine + Cystine	6.5	5.4	4.4
Phenylalanine +Tyrosine	10.6	8.7	7.0
Minerals (g/kg)			
Calcium	7.0	6.0	5.0
Phosphorous (Total)	6.0	5.0	4.5
Chlorine	1.5	0.8	0.8
Magnesium	0.4	0.4	0.4
Potassium	2.6	2.3	1.9
Sodium	1.5	1.0	1.0

Source: NRC (1998)

2.4.2 Gastrointestinal (GI) tract in pigs

Pigs have a relatively simple, single-chambered stomach (monogastric). There are five main parts digestive tract of the pig: the mouth, oesophagus, stomach, and small and large intestines (Figure 1). The mouth part is where food enters the digestive tract and mechanical breakdown of food begins. The teeth chew and grind food into smaller pieces. The oesophagus is a tube which carries the food from the mouth to the stomach. A series of muscle contractions push the food toward the stomach. The stomach is the next part of the digestive tract. It is a reaction chamber where chemicals are added to food (Rowan *et al.*, 2015).

The small intestine is a complex tube where its wall has many tiny finger-like projections known as villi, which increase the absorptive area of the intestine. The last major part of the digestive tract, the large intestine, is shorter, but larger in diameter than the small intestine. Its main function is the absorption of water. The large intestine is a reservoir for waste materials that make up the faeces. (Rowan *et al.*, 2015).

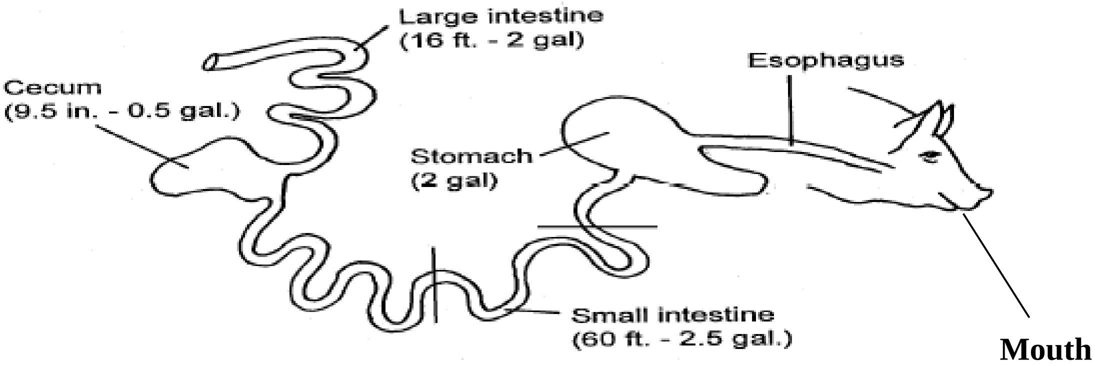


Figure 1. Digestive system of the pig (Joel, 2009)

2.5 Non-conventional feedstuffs and limitations of their use in livestock feeding

Non-conventional feed resources are those feeds that have not been traditionally used in livestock feeding and/or are not normally used in commercially produced rations for animals. A large number of agro-industrial by-products, aquatic herbages and animal wastes which have been identified, processed and used for feeding on farm animals are designated as non-conventional feeds (Onyimba *et al.*, 2009).

Examples of non-conventional feedstuffs include discarded biscuits, bakery waste, rice, wheat and maize bran, blood meal, cassava peels' and potato chips. Others are pito-mashes; brewers' spent grains, bone meal, molasses, sugar beet pulp, citrus pulp, yeast and distiller's soluble (Rhule *et al.*, 2007). Most livestock especially monogastric like pigs have slow growth rate when fed on some by-products because of poor feed intake and digestibility. This is because of the high fibre content in most of these by-products which reduce intake because of their bulkiness (Thomas *et al.*, 2010). The low feed intake experienced in non-conventional feedstuffs, could also be attributed to low palatability of most of these by-products.

Another major constraint in the use of non-conventional feedstuffs are the anti-nutritional factors (ANF) which interfere with the normal digestion, absorption and metabolism of feeds (physiological status), some of which may have deleterious effects on the animal's digestive system. Some inherent chemical compounds present in some feedstuffs interferes with the optimum utilization of nutrients especially proteins and carbohydrates. Anti-nutritional factors can be classified on the basis of their chemical nature into nitrogenous compounds, saponins, tannins, glucosinolate and phenolic compounds (Pathak, 1997). Fibre content in feedstuffs (mostly by-products of plant origin) is less important in relation to their feeding value in pigs. The cellulose, hemicellulose and lignin components, influence organic matter digestibility of feed. The variation on digestibility depends on the special characteristics of the fibrous components in the feeds (Kidder and Manners, 1978).

2.5.1 Utilization of fibrous feedstuffs in pig feeding

The increasing cost of feed ingredients especially energy and protein sources has been a serious constraint to the survival of livestock industry in developing countries. The situation calls for attention to be shifted towards the use of alternative feed ingredients or non-conventional feedstuffs that are locally available. Such feedstuffs are considered as waste and relatively cheaper compared to conventional feed ingredients (Adesehinwa, 2008). This is a way of solving the problem of using high cost conventional feed ingredients that are scarce and sustaining the livestock industry. Myer and Hall, 2004 reported that the following should be considered when using a by-product or edible waste as an alternative feed source. It must be available and in constant supply, free from potential health hazards, such as aflatoxins and palatable to the animal.

Information on the nutrient content must be established and should not have an adverse effect on the end products of the animals. However, there have been conflicting reports on ideal inclusion levels; which may be attributed to the extent of adulteration with the husk/hull. The shortages of raw materials for livestock feed production, particularly poultry, and pigs are numerous. The emphasis seems to be on the shortage of grains (basal energy feed) and protein supplements which together constitute about 70-80% of finished products (Noblet *et al.*, 1994). Potential benefits and effects of dietary fibre on animal health may be manifested through changes in a microbiota of the GIT. The composition of the CF in the diet influences the species and number of bacteria in the gut (Jensen *et al.*, 2003). Feed ingredients with a high concentration of dietary fibre, such as distillers dried grains with soluble (DDGS), are widely available as competitive source of energy and nutrients for swine feeding programs (Shurson *et al.*, 2012).

These ingredients (non-conventional) are limited because they contain a high concentration of dietary fibre (DF) that decreases the nutritional value of the diet (Zijlstra and Beltranena, 2013). The nutritional value is reduced because DF increases variability in digestibility of energy and nutrients. Dietary fibre is the sum of all plant derived carbohydrates that are indigestible to digestive enzymes in the gastrointestinal tract (GIT) of mammalians such as pigs and poultry. However, these carbohydrates are not only indigestible to GIT enzymes of mammalians, but they also reduce digestibility of nutrients (Crude protein, lipid, and starch) and efficiency of energy utilization (Gutierrez *et al.*, 2014).

Fibre is not digested by endogenous enzymes, and bacteria may ferment fibre (Varel and Yen, 1997), mostly in the large intestine but also in the small intestine (Jha *et al*., 2010; Jha and Leterme, 2012). Fibre fermentation produces volatile fatty acid (VFA) (mainly acetate, propionate, and butyrate) and gasses such as Hydrogen (H_2), Carbondioxide (CO_2), and Methane (CH_4) (Macfarlane and Macfarlane, 1993). The VFAs are important signalling molecules (Xiong *et al*., 2004) and serve as energy sources (Varel and Yen, 1997).

2.5.2 Effects of fibre on physiological functions of pigs

Dietary fibre (DF) is the composite of plant derived polysaccharides that are not degraded by digestive enzymes in the small intestine of monogastric animal like pigs and poultry.

A minimum level of fibre has to be included in pig diets to support normal physiological activity in the digestive tract (Wenk, 2001). Mateos *et al*. (2006) suggested that young pigs may have a maximum DF level of 6%. However, diets or ingredients with high fibre content >6% may negatively affect voluntary feed intake and nutrient digestibility in young pigs (Wilfart *et al*., 2007). The impact on fibre level on digestibility may differ with the properties of the fibre (soluble vs. insoluble) (Högberg and Lindberg, 2004).

DF has been found to be an effective alternative to growth promoters (Verstegen and Williams, 2002), to improve gut health (Williams *et al*., 2001) by modulating gut microbiota, improve growth performance and reduce post-weaning diarrhoea of the pigs (Mateos *et al*., 2006). Fibre may improve intestinal health through stimulation of the intestinal compartments (small and large intestine) functions (Longland *et al*., 1994), and it is usually associated with a reduction of potentially harmful products of protein fermentation (McBurney *et al*., 1987). The inclusion of high amount of fibre in the diet offered to pigs results in reductions in foregut and whole-tract digestibility of dry matter (Knudsen and Hansen, 1991), leading to a lower absorption of nutrients and energy.

The digestibility of nutrients in pig diets has been shown to be related to the origin and content of DF (de Vriesa *et al*., 2012). Evaluation of the available energy content of pig feeds is usually based on their digestible energy or metabolizable energy content (Noblet, 2006). It was found that high fibre content is responsible for adverse effects on the digestible energy content of feeds for pigs (Noblet and Perez, 1993). The origin and composition of DF could be responsible for large variations in their utilization (Chabeauti *et al*., 1991).

The physio-chemical properties of the DF source in carbohydrates (CHO) such as solubility, fermentation, viscosity and water-holding capacity (WHC) may lead to changes in the gut environment, altering the growth of the gut microflora (Regmi *et al*., 2011), which is beneficial by increasing size and length of small intestine, caecum and colon of pigs (McDonald *et al*., 2001; Jørgensen *et al*., 1996). Moreover, it affects the gut epithelium morphology by changing the hydrolytic and absorptive ability of the epithelium (Montagne *et al*., 2003). DF also provides an important energy source of epithelial cells due to a higher bacterial fermentation and hence increased production of short chain fatty acids (SCFA) and specifically butyrate (Barbara *et al*., 2010).

The acceptability of the alternative feed ingredients in pig diets depends on several factors, like the DF content, the degree of microbial fermentation in the large intestine and the extent of absorption and utilization of the volatile fatty acid (VFA) produced (Molist *et al*., 2014). The fibre sources are fermented in the GIT producing VFA, which in turn positively contribute as an energy supplement for pig (Lindberg, 2014). DF affects fermentation in the GIT by stimulating the growth or metabolism of special bacterial species (Williams *et al*., 2001).

They increase numbers of cellulolytic bacteria to enhance the hindgut fermentation and production of VFA, which decreases the pH of the gut content. A decrease in pH promotes growth of beneficial bacteria (such as *Bifidobacteria* spp., *Lactobacilli spp*.), at the expense of pathogenic ones like *Clostridium* or *Salmonella*, which contribute to enhance the health of host species (Bouhnik *et al.*, 2004). Jha *et al.* (2010) reported that the lower organic matter and starch digestibility of the hulled barleys and oats were likely due to greater insoluble DF content, which negatively affects accessibility and the action of endogenous enzymes required for insoluble DF digestion in the upper gut and microbial fermentation in the lower gut. The rate of fermentation of DF in the pig's intestines depends on its composition and physical-chemical properties, degree of lignification and particle size (Le Goff *et al.*, 2002) and transit time in the digestive tract.

Carbohydrates (CHO) represent the main fraction of a pig diet, accounting for more than 2/3rd of the dry matter (DM) (Knudsen, 1997). However, part of the CHO is not digested by the digestive enzymes of the small intestine and becomes available as a substrate for bacterial fermentation, mainly in the large intestine. The fraction of fibre, reduces nutrients and energy digestibility (Knudsen, 2001; Noblet, 2007; Jha *et al.*, 2010). The physico-chemical properties CHO such as solubility, viscosity and water-holding capacity (WHC)) (Regmi *et al*., 2011), also has a marked effect on nutrient digestibility along the gastro-intestinal tract (Knudsen and Hansen, 1991; Chabeauti *et al*., 1991; Molist *et al*., 2014). Consequently, the digestible energy content of diets is negatively and linearly affected by fibre (Noblet, 2007). Dietary fibre is better digested in adult sow than in growing pig in terms of energy (Noblet, 2007).

Fibre utilization has an effect on the growing pig intake, and this was reported earlier to be influenced by physical and chemical composition of the whole diet (Myer *et al.,* 1975), age and weight of the animal (Zivkovic and Bowland, 1970), adaptation to the fibre source (Pollman *et al*., 1979) and individual variation among pigs (King and Taverner, 1975). This is ascribed to differences in the physiological stage of pigs as there is a higher rate of degradation of fibre in the hindgut of mature pigs, compared with growing pigs, due to longer retention time consecutive to their higher GIT volume, combined with a lower feed intake per live weight (Le Goff *et al.*, 2002).

2.6 Brewers' spent grains (BSG)

BSG is a by-product after making beer in the brewery Industry. It contains 21-29% CP on DM basis (Westendrof and Wohlt, 2002). It is available and cheap but difficult to dry to low moisture content for easy of storage especially during the wet seasons. BSG consists largely of structural carbohydrates and protein remaining when barley is malted and mashed to release sugars for brewing. The removal of sugars and starches during the malting and mashing process makes BSG to be higher in fibre (cell-wall carbohydrates), protein, and some minerals than are in the foundation grains (Westendrof and Wohlt, 2002) . It is a concentrated source of digestible fibre, with good amino acid profile, B-vitamin and phosphorus contents (Shurson, 2003). With respect to animal feed, BSG has been found to be an excellent feed ingredient for ruminants, as well as benefits for humans (flour form in breads, snacks, biscuits).

Beyond its usefulness as an animal food by-product, some of its components are also being viewed as precursors of food grade chemicals or as energy sources in microbial fermentations (Gupta *et al*., 2010). BSG has also been used as an enzyme for removing organic materials from effluents and the immobilization of various substances (Mussatto, 2009). Both, wet and dry brewers' grains have similar feeding characteristics if fed to livestock. The wet brewer's grain is good if fed shortly after it is produced and has been used mainly as protein and energy supplement. Fresh brewers' grains contain about 700-760 g water/kg and have been fed to cattle, sheep and horses in fresh or silage form (McDonald *et al*., 2002), and to pigs in wet or dried form but high fibre (ADF 17-26% DM), makes them less suitable for pigs and poultry. In view of the reported shortages of conventional feeds for livestock and poultry, there is a need to develop technologies for using by-products obtained from food and agro-industries more efficiently and other non-conventional feeds as protein, and energy supplements. The quantity and time period during which they are available, storage properties, preparation, and preservation are determining factors for their possible use (Rajorhia, 1999).

2.6.1 Chemical composition of brewers' spent grains

BSG is mainly composed of the barley malt grain husks in mixtures of part of the pericarp and seed coats layer of the grains. BSG is rich in sugars, proteins and minerals, the chemical composition BSG may have significant variations due to a variety of factors, which include the variety of the barley used in the process as well as its harvest time and the conditions under which it was cultivated, the conditions used for malting and mashing and the amount and type of the adjuncts added in mixture with the barley malt (Robertson *et al.,* 2010; Mussatto, 2014). Nguyen (1996) and, Biswas and Naveen (2011) reported protein and fibre content to be around 20-32% and 70% dry basis, respectively.

The nutritional content of the material may vary from plant to plant and depending upon the type of grain used (barley, wheat, corn). Compositionally BSG has about 17% cellulose, 28% non-cellulosic polysaccharides, mainly arabinoxylans, and 28% lignin (Aliyu and Bala, 2011). There is wide variability in the nutrient composition of BSG depending on the brewery that produced it. Xylose, glucose, and arabinose are the most abundant monosaccharides found in BSG (Aliyu and Bala, 2011). BSG is composed of some minerals, vitamins, and amino acids. The minerals found in BSG are calcium, cobalt, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium and sulphur (Biswas and Naveen, 2011).

The crude fibre content (including lignin and carbohydrates mostly cellulose) in BSG is about 14-15% on a dry solid basis (Keilbach, 2009). Other fibre components include hemicellulose, pectin's, gums, mucilages, and maillard products. Total dietary fibre in BSG is about 56% of which 2.5% is soluble dietary fibre and 53.5% is insoluble (Biswas and Naveen, 2011). The variation in nutrient composition in BSG is due to types of barley, classification and harvest time, preservation method, malting and mashing conditions as well as type of adjuncts used during processing and brewing technology (Robertson *et al.,* 2010) (Table 2).

Table 2. Chemical composition of brewers' spent grains reported in different studies

Parameter	Minimum	Maximum	Mean
DM	21.0	29.2	24.5
CP	15	31	23.5
CF	11.3	20	15.8
Ash	1.2	5	3.7
NDF	47	54.6	49.9
ADF	23	24.7	23.7
Crude fat	9	19.6	11.0
EE	5.9	5.9	5.9
Cellulose	11	17	16.4
Lignin	4	28	11.7
TDN	70	79.1	74.3

Source: Muthusamy (2014)

2.6.2 Preservation techniques and sustainable utilisation of BSG

Due to high moisture content (70-75% in wet BSG), BSG can rapidly deteriorate due to chemical and microbiological reactions (Tang *et al.,* 2005). BSG imposes significant handling, storage and transportation challenges to brewing operations. Where storage may be required for downstream processing of BSG, then deterioration through microbial activity is perceived as a potential problem, unless the BSG can be stabilized post-production (Robertson *et al.,* 2010). BSG is intended for long storage, it is necessary to dry them so that they don't contain more than 10% moisture (wet basis) (Tang *et al.,* 2005; Boissinger *et al.*, 2005). Several methods have been proposed to prolong BSG storage time as freeze-drying, oven drying, sun-drying and ensiling (Bartolome *et al*., 2002).

Drying is an appropriate technique for the preservation of BSG as it reduces product volume, and consequently reduces transportation and storage costs (Aliyu and Bala, 2011). Amoah *et al*. (2013) proposed that BSG (wet) can be ensiled in polyethylene bags but sun drying has been suggested to be a cheaper way of processing WBSG. Breweries typically do not dry the BSG generated due to high energy costs involved. Instead, most breweries sell it for cattle feed, composting, soil amendments in farmlands or disposed towards landfills.

Many breweries have plants for BSG processing using two-step drying technique, where the water content is first reduced to less than 60% by pressing, followed by drying to ensure the moisture content is below 10% (Santos *et al*., 2003). A preservation study conducted by Bartolome *et al*. (2002) using oven and freeze drying, results showed that oven and freeze drying reduced the volume of the product without altering its composition. Brewers grains are usually fed dried to pigs, as they are easier to store and more stable (Blair, 2007), but they can also be fed wet or ensiled (Boessinger *et al*., 2005).

Ensiling (silage making) is a preservation method of BSG based on the spontaneous lactic acid fermentation under anaerobic conditions (FAO, 2012). The quality of the ensiled product (silage) depends on the feeding value of the material ensiled and on the fermentation products present: butyric acid, acetic acid, lactic acid and the amount of ammonia (FAO, 2012). Ensiling of BSG reduces the fibre content and with enhancement of other nutrients availability like protein, NFE, lipid and calcium (Onyimba *et al.*, 2009). For longer storage, it may be ensiled in an airtight trench silo, or in tightly tied plastic bag silage. The major challenge in a brewery are not only these wastes produced but also their bulkiness. With the emergence of global concerns on climate change, and environmental pollution, regulations call for reduction in waste generation, and the transition, to sustainable and green production methods (Biswas and Naveen, 2011). Brewers grains can be fed to pigs, but their high fibre content and the high quality of the protein, which is deficient in lysine, threonine and tryptophan, make them more suitable for pigs with low energy requirements such as gestating sows and boars, rather than to growing pigs and lactating sow, particularly in intensive production systems (Blair, 2007; Boessinger *et al.*, 2005).

2.7 Uses of brewers' spent grains

BSG has been considered a by-product used as animal feeds for a long time (Mussatto, 2009). With an increase in disposal cost due to legislation and corresponding decline in traditional disposal routes for the solid material (such as animal feed), alternative commercial uses for BSG are being sought. Various alternative applications of the BSG have been investigated for many years require targeted and practical technological developments. Those applications are: animal feed, human nutrition, substrate for microorganisms and enzyme production and production of value added products (Biswas and Naveen 2011). BSG, with its protein and energy levels, makes a good supplement to animals' food rations.

Both wets and dry BSG can be used in ruminant animal feed, due to its high content of protein. Most often used as a cattle feed, BSG has been shown to increase milk yields and total solids in the milk in dairy production operations (Mussatto *et al*., 2006). Low cost BSG when combined with inexpensive nitrogen sources, such as urea, can provide rich source of energy, essential amino acids, and other micronutrients to ruminant and monogastric animals (Belibasakis and Tsirgogianni, 1996).

2.7.1 Brewers' spent grains as a livestock feed

Feeding of BSG has been done to animals such as ruminants (cattle, goat), poultry, pigs, and fish. In a study, it was reported that cattle ate more of the BSG mix than of the control, perhaps because of the increased palatability of the BSG and the high moisture content (Phipps *et al*., 1995). Lazarevich *et al.* (2010) reported that BSG can be used in pig diets, but it tends to have a depressive effect on feed intake, DM and energy digestibility, animal performance and carcass dressing rate. In another study with pigs, although the amount of time to slaughter weight increased linearly from increasing levels of BSG (which replaced maize), the quality of the meat remained the same. Further, the percentage of harm in pigs increased quadratically with increasing levels of BSG (Yaakugh *et al.*, 1994) by reducing nutrient digestibility.

2.8 Performance of growing pigs fed on wet and dry BSG

The weight gain, feed intake and feed conversion efficiency are in some cases variable when BSG used as a feed but mostly similar in wet form compared with dry diets (Lawlor *et al*., 2002) and the lower weight gain can be attributed to a lower intake or digestibility of nutrients. Yaakugh *et al*. (1994) added 0, 12, 24 or 36% of dry BSG (dried) on the finishing period of pigs. They reported that, weight gains of 890 g /d with 0%, 655g/d with 12% and 24%, and 550 g/d with 36% BSG (dry). Altizio *et al*. (2000) included 20% wet brewer's grain

(BSG) on fattening swine diets starting at 40 kg. They obtained similar DMI compared to control animals. However, ADG was higher for control (930 g/d) than 20% WBG (833 g/d).

Aletor and Ogunyemi (1990) reported that only during the first 15 days the ADG was different among treatments (P<0.05) when used 0, 10, 20 and 40% of BSG (dry) was used and were similar in the consecutive feeding periods. Pelevina (2007) reported that ADG or feed efficiency did not differ significantly P>0.05) when 0, 5, 8 or 10% of BSG (dried) was added in swine diets. Meffeja *et al.* (2007), evaluated diets with 0, 20, 30 or 40% of ensiled BSG (wet), reported that DMI increased linearly; however, DM digestibility was similar in 0, 20 or 30% treatments (mean = 72.1%) and decreasing to 63.4% on 40% treatment. During fermentation of diets some nutrients may be modified. In temperate countries, BSG is only recommended for finishing pigs (over 60 kg) and lactating sow, at about 20% BSG of the diet, or 1-2 kg/d (Blair, 2007; Boessinger *et al.*, 2005), and up to 3kg/d (Edwards, 2002). Utilization of crude fibre by non-ruminants has been shown to vary considerably according to the fibre source (Galassi *et al*., 2004), degree of lignification, level of inclusion (Wang *et al.*, 2004 in Korea) and the extent of processing (Amaefule *et al*., 2009). Amaefule *et al*. (2006) in Nigeria reported that 0, 30, 35 and 40% BSG did not significantly (P>0.05) affect feed intake, ADG and FCR in weaner pigs but differed significantly (P<0.05) among grower pigs.

Ironkwe and Bamgbose (2011) reported that the performance of weaner pigs was significantly different (P<0.05) when 0 (diet 1), 10% (diet 2), 20% (diet 3) and 30% (diet 4) BSG replaced maize. Imonikebe and Kperegbeyi (2014) reported that average daily weight gain of weaner pigs was no significantly (P>0.05) difference across the treatment diets when fed to Diet 1 (0 %), Diet 2 (10 %), Diet 3 (20 %) and Diet 4 (30 %). The lower weight gain in Diet 4 with 30 % inclusion was due to the high fibre content, which reduced digestibility and utilization of nutrients, contained in the feed. However, there was no significant difference (P>0.05) among feed conversion efficiency of all the animals fed on the four diets. Fibre from BSG when fed to monogastric animal may significantly alter their fat and lean muscle content (Keilbach, 2009). Increasing BSG levels (>5%) significantly increased daily feed intake but negatively affected the growth performance of the monogastric animal (Khalili *et al.*, 2011).

2.9 Economic benefits of using BSG

Currently, supplying this wet BSG to local farmers for use as livestock feeds continued to be the main solution of the breweries for its elimination, since this is a cheap alternative that avoids the energy needed for drying the BSG (Mussatto, 2014). However, the cost of transporting BSG is significant depending on the distance from the industry to the farm. Therefore BSG is usually supplied to local farmers (preferentially no further than 8km from the brewery) in order to minimize the costs involved in its elimination. Nevertheless, in some cases, the BSG produced may surpass the demand for cattle feeds required by the nearby farmers (Mussatto, 2014).

Luu *et al.* (2003) reported that for a good economic return to pig production, the best solution are to take full advantage of local feed resources instead of using commercial concentrates. They reported that on 30% BSG replacement of the fish meal protein was the best with high gross margin than the control diet when 0, 30, 60 and 100% BSG diets were used to feed grower and finisher pigs. There was also significant ($P<0.05$) increase in financial benefits (gross margin) due to feeding of different levels of BSG diets to weaner pigs against the control diet (Babatunde *et al*., 1975). They reported that the diet containing 40% BSG (dried) significantly ($P<0.05$) reduced total feed cost more than any other level of BSG or control diet. In all cases, the feeding of 0% BSG (control) diet resulted in significantly higher ($P<0.05$) costs than BSG diets.

Amaefule *et al*. (2006) in Nigeria observed lower total feed cost of 40% BSG (dried) diet did not result in lower feed cost per kg weight gain. There might not be increased financial benefit as a result of increasing the inclusion level of BSG (dried) in the diet >35% in weaner and grower pigs. Therefore, from the economic point of view the optimum inclusion level of BSG in pig diet is 35%, since cost minimization and gross income optimization is observed at these levels. Meffeja *et al.* (2007) and Aguilera-Soto *et al.* (2009) reported that in tropical and subtropical climates, inclusion rates of 30% in weaner pigs and 40-50% in finishing pigs have been proposed and found to be cost-effective inspite of the performance losses. Imonikebe and Kperegbeyi (2014) reported that the marked difference between the prices of maize and BDG must have resulted in the significant reduction in the feed cost per kg diets recorded in this experiment.

2.10 Gaps in the literature

From the preceding literature, it is evident that BSG varied in nutrient composition and in the performance of pigs fed on BSG. The variation in nutritive value of BSG depends on variety of the barley used, harvest time and the conditions under which it was cultivated, the conditions used for malting and mashing and the amount and type of the adjuncts added in mixtures. Feed for livestock is becoming scarce due to decrease in cereal grains. Therefore, use of locally available and affordable feedstuffs like brewers' spent grains (BSG) is meaningful. The potential of using the BSG as a feedstuff for livestock is increasing. BSG has many components (fibre, protein, minerals and vitamins) which make it a potential feed ingredient.

The feeding capabilities of brewer's spent grain are, however, limited by its high crude fibre content and low degradability of the crude protein fraction especially in monogastrics. Diets or ingredients with high fibre content >6% may negatively affect voluntary feed intake, nutrient and energy digestibility in growing pigs. Therefore, the performance of growing pigs at different inclusion levels of BSG needs to be determined.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Study site

A feeding trial was conducted in Eastern Province, Bugesera district, Nyamata sector at a smallholder's pig farm. Bugesera is one the seven Districts of Eastern Province, located in the South Eastern plains of Rwanda, in the south-west of Eastern Province. It borders Republic of Burundi (Kirundo Province) in the South, Ngoma district to the East, Kigali city and Rwamagana district to the North. The districts consists of 15 Sectors (Nyamata, Rweru, Gashora, Nyarugenge, Mayange, Shyara, Mareba, Musenyi, Kamabuye, Juru, Ruma, Ntarama, Mwogo, Ngeruka and Ruhuha), 72 Cells and 581 Villages (Figure 2). It covers an area of 1337 Km^2 of which arable land is estimated at 91,930.34 ha. The average size of land cultivated per household is 0.59ha. (MINITERE, 2003). It has a total population of 363,339 people in the proportions of 177,404 males and 185,935 females (NISR, 2012). The vegetation is short grasses, shrubs and trees – a characteristic of arid and semi-arid areas with a temperature varying between 20°C and 30°C (MINITERE, 2003).

3.2 Collection site of brewers' spent grains

Brewers' spent grains (BSG) was collected from Skol Brewery Ltd and Bralirwa Industry. Skol industry is located in Kigali city and is the fastest growing brewery producing international quality beer in Rwanda. Bralirwa Industry is located in western province, Rubavu District. Skol industry uses natural ingredients like pure water, a unique blend of hops, rice and malted barley. Bralirwa Industry prefers to include local maize in its beer making process in addition to malted barley, yeast and sugar. Brewers' spent grains, a by-product of beer making from the two industries is sold to farmers for use as an alternative livestock feed resource.

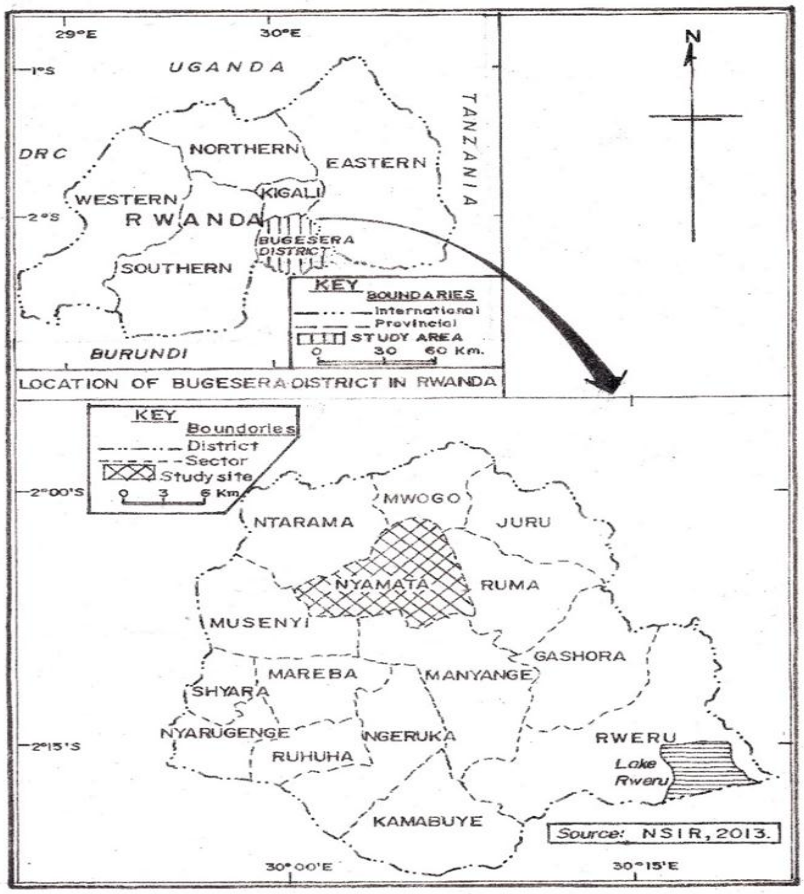


Figure 2. Administrative map of Bugesera District showing study site

3.2.1 Experimental diets

Brewers' spent grains used in the study was purchased from Skol Brewery Ltd, packed into polythene and transported to Bugesera district, Nyamata Sector where feeding trials were conducted. Sow and weaner meal (SWM) was bought from Zamura Feeds Ltd, in Musanze District.

Five diets with 0% BSG (control diet), 25%, 50%, 75% and 100% BSG (wet) inclusion levels replacing SWM were formulated as T1, T2, T3, T4, and T5 respectively. Each polythene bag of BSG was only opened at feeding time and mixed with SWM to avoid spoilage. The control diet (T1) was bought already compounded and contained whole maize, maize bran, soybean meal, fish meal, bone meal, sunflower, lime stone, cotton seed cake, DCP, swine premix and salt (Appendix 2). A mineral premix (Uganda general premix) was added to diet 5 or T5 once per week to prevent incidences of mineral deficiency.

3.2.2 Chemical analysis

The proximate analysis of experimental diets (BSG and SWM) was done at Rwanda Agricultural Board (RAB) laboratory using standard procedures of Association of Official and Analytical Chemists (AOAC, 1990). The samples of BSG and sow and weaner meal (SWM) were analysed for ME (Kcal/kg) by indirect methods as:

ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7 CF - 40.8 Ash (Wiseman, 1987)

3.3 Experimental animals

The pigs were housed on a rough concrete floor with open sided wooden wall of 1.5X1.5X1.5M, roofed with iron sheets. A total of ten (10) pens, with two feeders and one drinker per pen were used. Pigs were individually identified with ear tags. Thirty (30) gilts of Landrace x Pietrain crosses of 30 - 40±5 kg live weight were used. They were allocated to 10 pens with 3 pigs per pen. Proper hygienic environment (cleaning) was maintained throughout the experiment (Appendix 2).

3.4 Experimental design

In a completely randomized design (CRD), five (5) diets were randomly assigned to the pigs. This was done scientifically by ranking calculator numbers in excel. Diets were mixed at feeding time to avoid spoilage of BSG and each diet replicated twice. The pigs were given 7 days to acclimatize before commencement of data collection. Feeds were offered twice a day, at 08:30 hours and 3:30 hours and water provided *ad libitum* throughout the experimental period (42 days). Feed offered and any remainder in the feed troughs was weighed and recorded daily before next feeding to calculate feed intake. The statistical model was as follows:

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

Where Y_{ij}= Overall observation j^{th} of the i^{th} treatments, μ =overall mean, τ_i =effect of i^{th} treatment; and ε_{ij} = random error term.

3.5 Data collection

The parameters measured were feed intake (FI), average daily gain (ADG), feed conversion ratio (FCR) and economics (net returns) of using BSG.

FI (kg) was calculated as the differences between the quantity of feed offered and the left over before the next feeding.

ADG (kg/day) was calculated as [average final weight-Average initial weight]/7days per treatment.

FCR: This is the quantity of feed consumed (kg) per unit of live weight gain (kg) for each pig. FCR= {Feed intake (kg) in 7 days/ average weight (kg) in 7 days}.

Returns (benefits): Economics of using BSG were done using, variable expenses (cost of feed, labour, medicines and transport) and the values of live weight of pigs. Partial budget measures the cost of feed at different inclusion levels of BSG replacing SWM. The net returns of using BSG was determined by subtracting total expenses (Cost of feed, labour, medications and transport) from total income of sale of dressed carcass at 75% dressing.

3.6 Statistical analysis

The data on nutrient composition, final weight, ADG and FCR were subjected to Analysis of Variance (ANOVA) using the General Linear Model (GLM) of SAS 9.0 (2002). Initial weight was a covariate in the analysis of live weight changes. The means between diets were ranked using Tukey's pair-wise comparison test at 5% level of significance. Tukey's test was chosen since it is a good general statistical technique for carrying out all pairwise comparisons where means are ranked and put them into significance groups, while maximum experiment-wise error rate (MEER) are controlled under any complete or partial null hypothesis.

CHAPTER FOUR

4. RESULTS AND DISCUSION

4.1 Nutrient composition of brewers' spent grains

The results of nutrient composition analysis of Skol and Bralirwa BSG samples differed significantly (Table 3).

Table 3. Nutrient composition of BSG from two industries in Rwanda

	BSG	
Parameter on DM basis (%)	Skol	Bralirwa
DM	20.34[a]	20.9[a]
Ash	3.95[a]	3.59[b]
CP	26.6[b]	28.8[a]
Fat	1.45[b]	2.08[a]
CF	6.38[b]	9.02[a]
ME (MJ/kg DM)	13.8[a]	13.1[b]

[a, b] Means with different superscript in the row are significantly different ($P<0.05$, using Tukey' test); BSG=Brewers' spent grains

Dry matter content of BSG was 20.3 and 20.9% for Skol and Bralirwa samples, respectively, which is in agreement with the values reported by Ranjhan (1998) and Nissanka *et al*. (2010) in the range of 20-21.7% DM. Amaefule *et al.* (2006), Ironkwe and Bamgbose (2011) and Iminokebe and Kperegbeyi (2014) in Nigeria, all reported higher DM content ranging from 89.5± 0.1 to 91.5% for BSG in dry form. The CP content was 26.6 and 28.8 % for Skol and Bralirwa samples respectively. Nissanka *et al*. (2010) and Iminokebe and Kperegbeyi (2014) reported CP ranging from 18 to 19.7%. A higher CP of 31% was reported by Dung *et al*. (2002). The CF content of BSG was 6.39 and 9.02% for Skol and Bralirwa samples respectively and were lower than the values ranging from 11.3-21%, reported by Dong and Ogle (2003) in Vietnam, Amaefule *et al*. (2006) in Nigeria, Senthilkumar *et al.* (2010) in India, Nissanka *et al*. (2010) in Sri Lanka and Iminokebe and Kperegbeyi (2014) in Nigeria.

The crude fibre content depends on the types of barley used, adjuncts added, malting and brewing processes. In this study, Skol Industry includes rice and hops as an adjunct and Bralirwa add maize as an adjuncts. Fat contents were1.45 and 2.08% for Skol and Bralirwa samples respectively. Metabolizable energy (ME) was 13.8 and 13.1MJ/kg DM for Skol and Bralirwa samples respectively, which were higher than 7.3 MJ/kg DM reported by Dong and Ogle (2003). Muthusamy (2014) reviewed different studies on nutrient composition of BSG and found variations in composition. The variations in nutrient composition of BSG were mainly due to the variety of barley used (vary in fibre content), harvest time, method of preservation, malting processes and the type of adjuncts used during processing and brewing technology (Robertson *et al*., 2010).

Crude protein content decreased gradually with the delay of harvest time of barley due to protein synthesis being inhibited by the weak photosynthesis at the mature stage (Throop, 2005). The variations in nutrient composition of BSG in the two industries (Skol and Bralirwa) were due to the adjuncts added, malting and mashing procedures used during brewery. Bralirwa Industry sample was high in CP, but Skol Industry sample was selected for use in this study based on the location, because transport cost was bound to increase the overall feed and study costs.

4.2 Nutrient composition of experimental diets

Results of nutrient composition analysis of BSG and sow and weaner (SWM) showed that there were significant differences between the two (Table 4). The ingredients used to compound SWM included whole maize, maize bran, soybean cake, fish meal, bone meal, sunflower cake, limestone, cotton seed cake, DCP, swine premix and table salt. The DM content of BSG and SWM were 20.3 and 99.8 % respectively which are closer to values reported by Dong and Ogle (2003) where BSG and concentrates had 25 and 88% DM respectively. Amaefule *et al*. (2006) in Nigeria reported higher DM in BSG (dried) as 89.5 and lower DM in concentrates as 91 % respectively. The BSG used was in the dry form. The CP was 26.6 and 13.4 % for BSG and SWM respectively. Dong and Ogle (2003) reported 23.6 % CP in BSG and 18.8% CP in concentrates. The differences were due to the feed ingredients used in the SWM and BSG based diets. BSG was the residue from 30% barley grains residues, 50% broken rice residues and 20% germinated rice residues, with yeast whereas concentrates contained 52% broken rice, 33% rice bran, 14% fish meal and 1% bone meal.

Table 4. Nutrient composition of experimental diets fed to growing pigs

	Diets	
Parameter on DM basis (%)	BSG	SWM
DM	20.3[b]	99.8[a]
Ash	3.95[b]	7.62[a]
CP	26.6[a]	13.4[b]
Fat	1.45[b]	3.60[b]
CF	6.38[a]	1.39[b]
ME MJ/kg DM	13.8[b]	15.6[a]

[a, b] Means with different superscript in the row are significantly different (P<0.05, using Tukey's test); BSG=Brewers' spent grains; SWM=Sow and weaner meal

The crude fibre content of BSG and SWM was significantly different (P<0.05) at 6.38 and 1.39% respectively and the fibre increased with an increase in BSG (Table 5). These results were lower than the findings of Amaefule *et al*. (2006) and Dong and Ogle (2003). Fats in BSG and SWM were 1.45 and 3.6% respectively and were significantly (P<0.05) lower than results reported by Amaefule *et al*. (2006) and Dong and Ogle (2003). The diets (SWM and BSG) had different ingredients compared to those used in this study. Metabolizable energy (ME) values in BSG and SWM were 13.8 and 15.6 MJ/kg DM respectively, which were higher than 7.3 and 12.9 MJ/kg DM for BSG and concentrates respectively reported by Dong and Ogle (2003). The increase in BSG in the diets increased CP and fibre but decreased ME (Table5).

The nutrient composition of diets used at different inclusion levels of BSG increased CP and fibre with an increase in BSG but ME and DM decreased (Table 5). Jørgensen *et al.* (1996) reported that BSG is high in protein compared to SWM and level of protein increased to an increase in BSG which is in agreement with the findings of this study (Table 5). The most important factor which may influence the digestibility of protein is high fibre as contained in BSG and fibre increased with increase in BSG (Table 5). Grower pigs are unable to digest high fibre feeds (>6%), but due to high CP, it can be included in the feed to a certain inclusion level (6% BSG) (Mateos *et al.* (2006).

Table 5. Calculated nutrient composition at different inclusion levels of BSG

	BSG inclusion levels				
Parameter	0% (T1)	25% (T2)	50% (T3)	75% (T4)	100% (T5)
CP (%)	13.4	16.8	20	23.4	26.6
CF (%)	1.39	2.63	3.89	5.13	6.38
DM (%)	99.8	79.9	60.1	40.2	20.3
ME (MJ/kg DM)	15.6	15.2	14.7	14.3	13.8

4.3 Performance of growing pigs fed BSG

The performance of growing pigs fed on BSG based diets differed significantly (P<0.05) (Table 6). This might be due to diet composition (fibre, CP and ME) at different inclusion levels of BSG (Table 5) where CP and CF increased with increase in BSG. The differences (P<0.05) were observed in Average daily feed intake (ADFI), average weight gain (ADG), feed conversion ratio (FCR) and net profit at different inclusion levels of BSG (Table 6).

Table 6. The performance of growing pigs fed BSG

	BSG inclusion levels				
Parameters (kg)	0% (T1)	25% (T2)	50% (T3)	75% (T4)	100% (T5)
Initial average weight	40.4^{a}	38^{a}	41.2^{a}	40.8^{a}	39.4^{a}
Final average weight	53.3^{a}	51.3^{a}	52.3^{a}	46.1^{b}	33.0^{c}
Weight gain/ week	2.15^{a}	2.22^{a}	1.86^{a}	0.875^{b}	-1.07^{c}
ADG	0.308^{a}	0.317^{a}	0.266^{a}	0.125^{b}	-0.153^{c}
ADFI/pig/day	2.31^{c}	3.81^{a}	4.14^{a}	3.84^{a}	2.97^{b}
FCR	7.56^{b}	12.02^{b}	15.7^{b}	30.9^{a}	-18.8^{c}

$^{a, b, c,}$ Means with different superscript in the row are significantly different (P<0.05, using Tukey)

4.4 Feed intake

The average daily feed intake (ADFI kg/day/pig) per pig significantly (P<0.05) increased with an increase in BSG for T1, T2, T3 and then decreased from T4 to T5 (Table 6). T1 and T3 had the lowest and highest ADFI respectively. The lowest feed intake in T1 was probably due to high DM in SWM (Table 5). Crude protein and fibre contents increased with an increase in BSG in T1, T2, T3, T4 and T5 (Table 5). Pigs on T5 consumed little amount of BSG, due to high CF and low DM content (Table 5), which tended to reduce feed intake and digestibility (Noblet, 2007) and led to low intake as well as the poor performance. Feed intake differed significantly based on the form of BSG used (wet or dry) as well as the animal. The decrease in feed intake may be attributed to the high crude fibre content of the diets which interfered with nutrient availability and digestibility (Table 5).

Weekly feed intakes (WFI) were significantly (P<0.05) different (Table 7). Weekly feed intakes (WFI) significantly (P<0.05) increased with time, where T1 weekly intake was lower than other treatments (T2, T3, T4and T5) throughout the experiment. Weekly feed intake on the 4th and 5th week for T2, T3 and T4 were not significantly (P>0.05) different, whereas lower intake was in T1 due to high DM content in SWM (Table 5). DM content decreased with increase of BSG in the diets (Table 5). Feed intake of pigs on diet T3 and T4 were similar in the 1st, 2nd 3rd and 5th week (Table 7).

Table 7. Average weekly feed intake (kg/week/pig) at different inclusion levels of BSG

	BSG inclusion levels on DM basis				
Week	0% (T1)	25% (T2)	50% (T3)	75% (T4)	100% (T5)
1	15.8^{c}	20.7^{abc}	25.4^{a}	22.5^{ab}	16.8^{bc}
2	14^{d}	23.3^{b}	25.7^{a}	25.1^{ab}	20.9^{c}
3	16.3^{c}	28^{ab}	30.2^{a}	25.6^{b}	19.7^{c}
4	16.2^{b}	28^{a}	29.8^{a}	26.5^{a}	19.3^{b}
5	16.3^{b}	28^{a}	30.3^{a}	26.8^{a}	19.3^{b}
6	18.3^{d}	32^{b}	32.3^{b}	34.7^{a}	20.9^{c}

$^{a,\ b,\ c,\ d}$ Means with different superscript in the row are significantly different (P<0.05; using Tukey's test).

The results were different from that reported by Rijal *et al*. (2009) at 0, 10, 20 30 and 35% BSG (dried) in T1, T2, T3, T4 and T5 respectively. They reported that, daily feed consumption of the piglet receiving T1, T2 and T3 were similar but were significantly (P<0.05) higher than those in the piglet groups receiving T4 and T5 diets.

Imonikebe and Kperegbeyi (2014) in Nigeria reported that feed intake significantly decreased with an increase in BSG (dried) when up to 30% BSG was used to feed pigs which is in agreement with the results of this study. The control diet used contained maize, soybean meal, fish meal, bone meal, Limestone, common salt and premix. Amaefule *et al*. (2006) results are in agreement with this study (Table 6). They reported that daily feed intake did not differ significantly in pigs (weaner and grower) fed BSG (dried) at 0%, 30, 35 and 40% inclusion levels. BSG replaced white maize from the control (diet 1) which contained white maize, groundnuts cake and offal (maize and wheat) fortified with bone meal, salt, and vitamin premix, whereas in this study BSG replaced the already compounded SWM.

Feed intake is influenced by the physical and chemical composition of the whole diet (Myer *et al.,* 1975), age and weight of the animal (Zivkovic and Bowland, 1970), adaptation to the fibre sources (Pollman *et al*., 1979) and individual variation among pigs (King and Taverner, 1975). The adaptation to the feed is very crucial, where livestock needs to be given at least six weeks before commencement of the study (Pollman *et al.*, 1979). The adaptation period influenced feed intake, where the first 2 weeks intake was low and increased with time during the experiment (Table 7). This was due to the previous management practices where pigs were fed on maize bran alone (feed) mixed with water. There was an increase in intake in T4 with time, among the five treatments. T4 had high intake on week 6, than others and low intake in T1 (Table 7). High DF levels in BSG diets decrease the voluntary feed intake of the animal as a consequence of gut fill, compromising the energy intake (da Silva *et al*., 2012) (Table 5).

4.5 Average daily gain

The average daily gains (ADGs) were significantly (P<0.05) different in T1, T2, T3, T4 and T5 (Table 6). T2 and T5 had the highest and lowest ADG respectively (Figure 3).

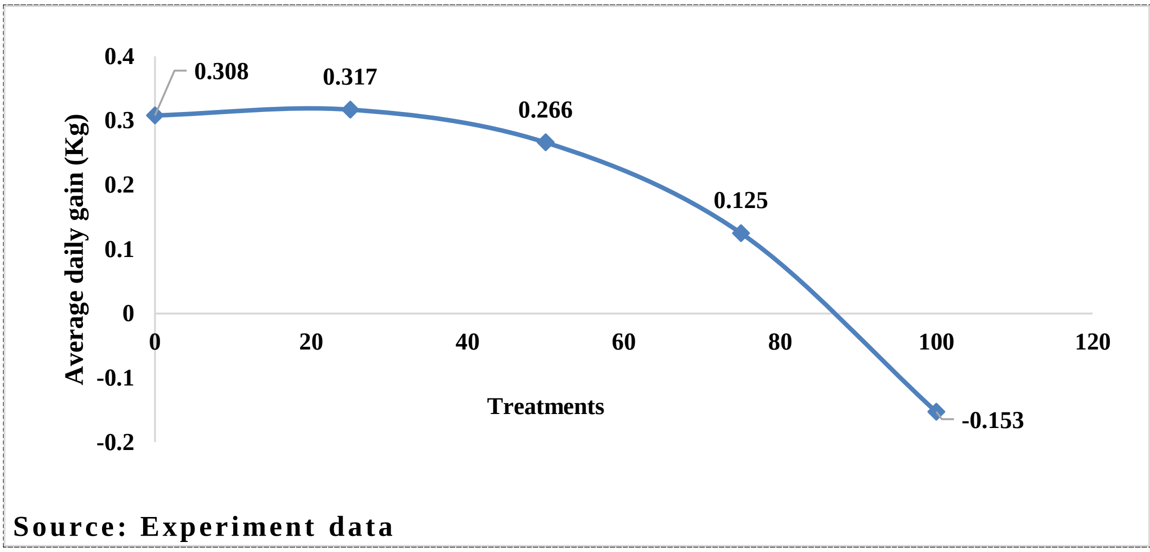


Figure 3. The effects of BSG on ADG at different inclusion levels

T3 (50% BSG) had similar ADG (P>0.05) with T1 (0% BSG), probably due to high CP contained in BSG (Table 5). The ADG of pigs in T2 was higher than T1 probably due to CP in BSG (Figure 3). Pigs fed on 50% BSG (T3) to increase weight equal to T2 probably might take more days (Figure 3). Grower pigs are not able to digest high dietary fibre (DF) feeds (>6%), but due to high CP, fibre can be included in the feed at 6% level (Mateos *et al*., 2006). DF in this study increased with an increase in level of BSG which have probably depressed feed intake (Table 5). Imonikebe and Kperegbeyi (2014) in Nigeria reported that when 0% (diet 1), 10% (diet 2), 20% (diet 3) and 30% (diet 4) BSG replaced maize were used to feed weaner pigs, ADGs were not significantly (P>0.05) different. The higher and lower ADGs were reported in T1 and T5 respectively, probably due to the high fibre content, which reduced digestibility and utilization of nutrients, contained in the feed. These are in agreement with the results of this study, where ADGs in T1, T2, and T3 BSG were not significantly (P>0.05) different (Table 6) based on the BSG replacement (BSG replaced maize and in this study BSG replaced already compounded SWM).

The variations of fibre content in BSG can influence their utilization by livestock (Table 5 and 8). Amaefule *et al*. (2006) reported that ADGs were similar for weaner pigs (49 days) but significantly different to grower pigs when 0 (diet 1), 30 (diet 2), 35 (diet 3) and 40% (diet 4)

BSG was used. Higher ADG was recorded in diet 1 and 3 whereas lower ADG was observed in diet 2.

The significant difference in ADG in grower pigs was probably due to their initial weight. Weaner pigs had the initial weight of 6.25 to 6.5kg and grower pigs had 19-20kg which led to high intake as well as ADG. Feed intake and growth rate was higher in grower than weaner pigs. Diet 1 (control) contained white maize, groundnut cake (GNC) and offal (maize and wheat) fortified with bone meal, salt, and vitamin premix while in the other diets, BSG replaced white maize. These results are not in agreement with the results of this study where grower pigs weighed 35 to 45kg and BSG replaced already formulated SWM. The inclusion of BSG at 10 to 15% in grower pigs diets did not depress ADG, although, nutrient digestibility was lowered (Pelevina, 2007 & Babatunde *et al*., 1975). Kornegay (1973) reported that high BSG levels in pigs' diets depressed feed intake and growth rate.

The weekly weight gain results are presented in Table 8. The weight gains within six weeks in the five treatments were significantly (P<0.05) different.

Table 8. Average weekly live weight of grower pigs fed BSG at different inclusion levels

		Weekly weight change					
Diet	Initial	1	2	3	4	5	6
T1 (0% BSG)	40.4	43.3[a]	44.9[a]	46.7[a]	48.6[a]	50.3[a]	53.3[a]
T2 (25% BSG)	38	40.6[a]	44.6[a]	47.1[a]	48.3[a]	49.1[a]	51.3[a]
T3 (50% BSG)	41.2	43.6[a]	46.2[a]	48.2[a]	49.2[a]	50.3[a]	52.3[a]
T4 (75% BSG)	40.8	39.4[a]	40.1[b]	41.8[b]	43.5[b]	44.8[b]	46.1[b]
T5 (100% BSG)	39.4	33.5[b]	32.6[c]	32.6[c]	32.8[c]	33.0[c]	33.0[c]
Probability	Ns	0.0001	0.0005	0.0001	0.0001	0.0001	0.0001

[a, b, c] Means with different superscript in the columns are significantly different (P<0.05; using Tukey's test)

The composition of experimental diets (protein, fibre and ME MJ/kg DM) changed with an increase in BSG (Table 5). This led to variations in weight gain during the experiment. Weekly weights of pigs on T1, T2 and T3 diet from 1st to 6th week did not differ significantly (P>0.05) (Figure 4). However, weekly weight gains of pigs on T5 was lower throughout the experiment. This was probably due to high fibre and low DM content in BSG which increased with the increase in BSG (T5) (Table 5).

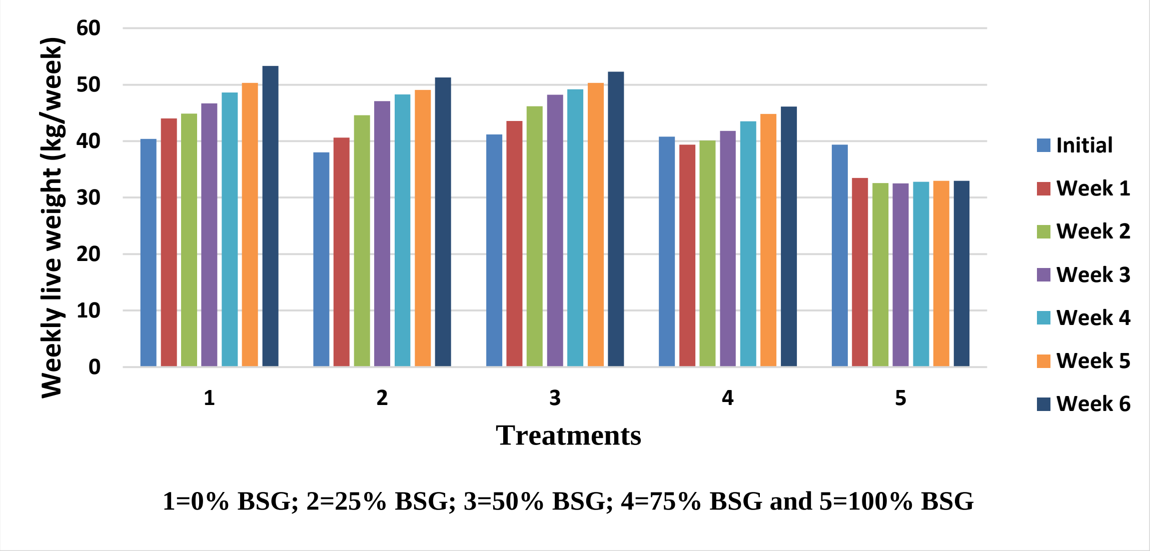


Figure 4. Weekly live weight of growing pigs fed BSG at different inclusion levels

The final weights (FW) in this study were significantly (P<0.05) different where T5 had lower FW throughout the experiment (Figure 4). Pigs on diets T1, T2 T3 and T4 increased weight weekly but T5 decreased weight abruptly (Figure 4). The FW (6th week) of pigs on T1, T2 and T3 were not significant (P>0.05) different (Table 8 and Figure 4). The results of this study are in agreement with those reported by Rijal *et al*. (2009). They reported that, live weight of pigs decreased from 8th-12th week (4th -6th fortnight) with increasing levels of BSG from 0, 10, 20, 30 to 35% BSG (dry) in T1, T2, T3, T4 and T5 respectively. However, diets T1, T2 and T3 diet from 2nd-12th week (1st-6th fortnight) did not vary significantly (P>0.05) but T4 and T5 values differed significantly (P<0.05).

Adaptation probably had effects on the intake as well weight gain. In this study, pigs on T4 (75% BSG) lost weight in the 1st and 2nd week and then gained weight from 3rd to 6th week (Figure 4). This was attributed to high dietary crude fibre intake (Yaakugh and Tegbe, 1990) (Table 5). The lower digestibility of BSG can be attributed to the complex fibre-starch–protein matrix (Jha *et al*., 2015), which limits the accessibility and action of endogenous enzymes for degradation in the upper gut and microbial fermentation in the lower gut, resulting in lower degradability of dietary fibre (Jha and Leterme, 2012).

4.6 Feed conversion ratio

Feed conversion ratio (FCR) for the different inclusion levels of BSG were significantly (P<0.05) different but similar (P>0.05) for T1, T2 T3 and T4 with 7.56, 12.02, 15.7 and 30.9 respectively (Table 6). This study observed the highest FCR in T4 (75% BSG) and lowest in T5 (100% BSG). Pigs increased their feed intake in order to meet their requirements, and this led to an increase in FCR. The higher FCR in T4 was due to increase in feed intake, low weight gain (Table 6) and high moisture content in BSG (Table 5). Increase in inclusion levels of BSG increased fibre and protein content in the diets (Table 5) and high crude fibre content adversely affected the digestibility of available nutrients (Yaakugh and Tegbe, 1990).

Imonikebe and Kperegbeyi (2014) in Nigeria reported that FCR did not significantly (P>0.05) differ when 0, 10, 20 and 30% BSG (dry) was fed to weaned pigs. BSG partially replaced maize in the four diets, which was different from this study where BSG (wet) replaced a compounded SWM, and the BSG was fed wet. Amaefule *et al*. (2006) in Nigeria reported that FCR differed significantly (P< 0.05) with 0, 30, 35 and 40% inclusions of BSG for grower pigs but FCR were similar (P>0.05) for weaner pigs. They reported that pigs fed 0% (control) and 35% BSG diets had similar weight gain and FCR. They concluded that the optimum inclusion level was 35%, and levels >35% adversely affected the weight gain and FCR.

Babatunde *et al.* (1975) and Yaakugh and Tegbe (1990) observed that grower pig fed diets with 15% and 35% BSG respectively had similar (P>0.05) growth rate and FCR compared to the control diet. Fibre levels >6 % in the diet has an effect on feed intake in growing pigs (Table 5) as a consequence of gut fill, compromising the energy intake of pigs (da Silva *et al*. 2012) which limits growth rate. A combination of digesta passage rate, digestibility, fermentability, and viscosity contributes to nutrient availability and commensal bacteria (neither benefits from the other nor provokes any harm) colonization in the lower gastrointestinal tract (Metzler-Zebeli *et al*., 2010; Regmi *et al*., 2011).

4.7 Economic benefits of using BSG

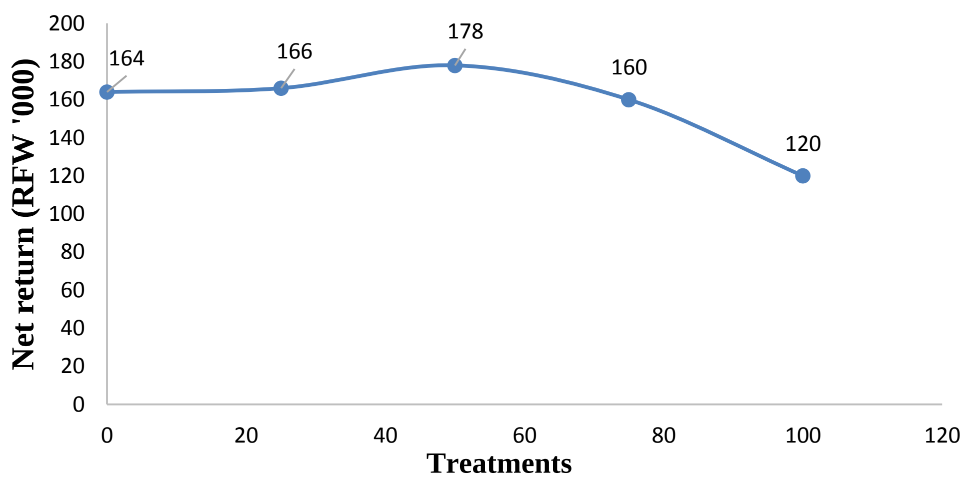
The feed cost decreased with an increase in BSG and returns were significantly (P<0.05) different as shown in Table 9 and Figure 4.

Table 9. Economic benefits of using BSG in growing pigs

Parameter (RFW '000)	0% (T1)	25% (T2)	50% (T3)	75% (T4)	100% (T5)
Total income*	240	231	236	207	149
Feed cost*	62	46	38	28	11
Transport cost*	7	11	12	11	9
Medicines*	2	2	2	2	2
Labour*	6	6	6	6	6
Total expenses*[1]	77	65	57	47	28
Net returns*	164	166	178	160	120

[1]Feeds, medicines, labour, transport,

*(*RFW=Rwandan Francs); 1USD=776 RFW; KES= Kenya Shilling, 1KES=7.5 RFW*



Source: Experiment data

Figure 5. Net returns of pigs fed BSG

Net returns were different in T1, T2, T3, T4 and T5 with 164, 166, 178, 160 and 120 Rfw (`000) respectively (Figure 4), equivalent to 21.9, 22.1, 23.7, 21.3 and 16 KES (`000) respectively. The highest and lowest net returns were in T3 and T5 respectively (Figure 4). Higher returns were due to high feed intake, low fibre in BSG (Table 5 and 9) with high growth rate. Pigs on T3 (50% BSG) performed similar with T1and with low feed cost and higher net returns (Table 9). ADG was not significantly (P>0.05) different from T1 and T3 (Table 6) but T2 had higher ADG (Figure 3). The inclusion levels of BSG at 50% had higher net returns than T1 and T2; whereas T5 had the lowest net returns (loss). Feed cost decreased with an increase in BSG, but transport cost of BSG and SWM varied as well as the amount consumed per diet.

Rijal *et al*. (2009) reported a reduction of feed cost when up to 20% BSG substitution was used for crossbred weaner pigs without any adverse effect on performance. There was an increment in the level of substitution of BSG >20%, there was less energy content than the requirement. This is not in agreement with this study where up to 50% BSG did not negatively affect the performance of growing pigs with better net returns than T1.

Amaefule *et al*. (2006) observed lower total feed cost at 40% BSG (dry) diet but did not result in lower feed cost per kg weight gain and increased gross margin, suggesting that there might not be an increased financial benefit as a result of increasing the inclusion level of BSG in the diets above 35%. They concluded that the optimum inclusion level of BSG in weaner and grower pig diets be at 35% BSG since cost minimization and gross margin are highest (numerically and statistically) at this level. This is not in agreement with the results of this study, where 50% BSG (T3) was more cost effective than T1 (0% BSG), due to variations of transport cost (Figure 4). The BSG (dried) diets replaced white maize partially and all diets were fortified with bone meal, salt and vitamin premix, which is different from this study where concentrates were bought already compounded.

Babatunde *et al*. (1975) reported that there was significant (P<0.05) increase in financial benefits (gross margin) due to the feeding of different levels of BSG diets to weaner pigs against the control diet. They pointed out that, irrespective of the stage of growth; it is more beneficial to include BSG at 35% level in pig diets which significantly (P<0.05) reduced total feed cost more than any other level of BSG or control diet. Feeding of 0% BSG (Control) diet resulted in significantly higher ($P<0.05$) costs than other BSG diets, which is in agreement with this study where T1 had higher feed cost hence lower net profit.

Determining and fulfilling the nutrient requirements of commercial strains of pig is one of the crucial considerations for pig production. Limited numbers of conventional feed ingredients are available to choose from for the formulation of balanced monogastric animal feeds in Rwanda. Grains are quite insufficient, therefore, there is a competition among monogastric livestock, humans and other livestock for most of the ingredients. The non-conventional feed ingredients, which are also reasonably affordable and locally available, may be the very prospective ones to solve the growing feed crisis. Therefore, extensive use of those locally feedstuffs like BSG would enhance further expansion of the pig industry. This study investigated the effects of different proportion of BSG inclusion in a SWM mix on pig performance (feed intake, growth rate, feed conversion ratio) and economics of production.

CHAPTER FIVE

5. CONCLUSIONS AND RECCOMMENDATIONS

5.1 Conclusions

The following are conclusions made from this study.

1. The nutrient composition of BSG from the two breweries (Skol and Bralirwa Industries) in Rwanda varies.
2. The inclusion of up to 50% in the diet of growing pigs had similar performance with the control diet (0% BSG). Therefore, the maximum replacement of SWM with BSG is 50%.
3. BSG at 50% had no negative effect on the performance and gave higher net returns compared to SWM.

5.2 Recommendations

1. It is recommended that BSG can replace part of SWM to reduce cost of production.
2. Due to increased feed cost for pig production, the government of Rwanda should sensitize farmers towards the use of BSG and a 50:50combination of BSG: SWM is recommended with high economic benefit and lower cost of production.

5.2.1 Future research

1. The high moisture contents in BSG, makes it bulky limits overall intake. Therefore, preservation techniques of BSG should be studied in Rwanda at industry and farm level.
2. More research to be done on nutrient composition (amino acids, vitamins, ADF, and NDF) of BSG.
3. The performance as well as digestibility of nutrients (amino acids, fibre, vitamins and minerals) by pigs fed diets based on BSG preserved by different techniques and optimum inclusion level in growing pigs.
4. Studies on the effect of BSG at different inclusion levels on carcass quality.

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APPENDICES

Appendix 1. Experimental animals

(Photo taken by Author, 2016)

Appendix 2. Nutritional value of SWM from Zamura Feeds Ltd per 500g

Parameters	Amount
Metabolizable energy Kcal/Kg	3600
Crude protein %	17
Crude fibre %	5
Moisture %	11
Calcium %	0.7
Phosphorous %	0.8
Vitamin A, IU/Kg	11000
Vitamin D3, mg/kg	2300
Vitamin E, IU/Kg	20
Salt %	0.4

maize, maize bran, Soya bean meal, fish meal, bone meal, sunflower, limestone, cotton seed cake, DCP, swine premix and salt

Appendix 3. ANALYSIS OF VARIANCE (ANOVA)

ANOVA OF NUTRIENT COMPOSITION OF BSG SAMPLES

Dependent Variable: Dry Matter (DM)

Source	DF	SS	MS	FV	Pr > F
Model	1	0.57660000	0.57660000	3.93	0.1186
Error	4	0.58760000	0.14690000		
Corrected Total	5	1.16420000			

R-Square	Coeff Var	Root MSE	DM Mean
0.495276	1.856055	0.383275	20.65000

Dependent Variable: Crude protein (CP)

Source	**DF**	**SS**	**MS**	**FV**	**Pr > F**
Model	1	7.30406667	7.30406667	38.07	0.0035
Error	4	0.76746667	0.19186667		
Total	5	8.07153333			

R-Square	CV	Root MSE	CP Mean
0.904917	1.579420	0.438026	27.73333

Dependent Variable: Crude fibre

Source	**DF**	**SS**	**MS**	**F Value**	**Pr > F**
Model	1	10.42801667	10.42801667	45.62	0.0025
Error	4	0.91426667	0.22856667		
Corrected Total	5	11.34228333			

R-Square	CV	Root MSE	Fibre Mean
0.919393	6.207571	0.478086	7.701667

Dependent Variable: Crude fat

Source	**DF**	**SS**	**MS**	**F Value**	**Pr > F**
Model	1	0.58906667	0.58906667	18.75	0.0123
Error	4	0.12566667	0.03141667		
Corrected Total	5	0.71473333			

R-Square	CV	Root MSE	Fat Mean
0.824177	10.05184	0.177247	1.763333

Dependent Variable: Ash

Source	DF	SS	MS	F Value	Pr > F
Model	1	0.19081667	0.19081667	18.68	0.0124
Error	4	0.04086667	0.01021667		
Corrected Total	5	0.23168333			

R-Square	CV	Root MSE	Ash Mean
0.823610	2.679917	0.101078	3.771667

Dependent Variable: Metabolizable energy (ME)

Source	DF	SS	MS	F Value	Pr > F
Model	1	0.90152584	0.90152584	18.32	0.0129
Error	4	0.19688363	0.04922091		
Corrected Total	5	1.09840947			

R-Square	CV	Root MSE	ME Mean
0.820756	1.650807	0.221858	13.43936

ANOVA OF NUTRIENT COMPOSITION OF BSG AND SWM

Dependent Variable: Dry matter (DM)

Source	DF	SS	MS	F Value	Pr > F
Model	1	7439.873067	7439.873067	93681.5	<.0001
Error	4	0.317667	0.079417		
Corrected Total	5	7440.190733			

R-Square	CV	Root MSE	DM Mean
0.999957	0.507278	0.281810	55.55333

Dependent Variable: Crude protein (CP)

Source	DF	SS	MS	F Value	Pr > F
Model	1	263.4762667	263.4762667	1198.35	<.0001
Error	4	0.8794667	0.2198667		
Corrected Total	5	264.3557333			

R-Square	CV	Root MSE	CP Mean
0.996673	2.344106	0.468899	20.00333

Dependent Variable: Crude fibre (CF)

Source	DF	SS	MS	F Value	Pr > F
Model	1	37.40006667	37.40006667	829.88	<.0001
Error	4	0.18026667	0.04506667		
Corrected Total	5	37.58033333			

R-Square	CV	Root MSE	CF Mean
0.995203	5.461984	0.212289	3.886667

Dependent Variable: Fat

Source	DF	SS	MS	F Value	Pr > F
Model	1	6.95526667	6.95526667	177.58	0.0002
Error	4	0.15666667	0.03916667		
Corrected Total	5	7.11193333			

R-Square	CV	Root MSE	Fat Mean
0.977971	7.832679	0.197906	2.526667

Dependent Variable: Ash

Source	DF	SS	MS	F Value	Pr > F
Model	1	20.16666667	20.16666667	2287.33	<.0001
Error	4	0.03526667	0.00881667		
Corrected Total	5	20.20193333			

R-Square	CV	Root MSE	Ash Mean
0.998254	1.623581	0.093897	5.783333

Dependent Variable: Metabolizable energy (ME)

Source	DF	SS	MS	F Value	Pr > F
Model	1	4.42506545	4.42506545	2084.42	<.0001
Error	4	0.00849171	0.00212293		
Corrected Total	5	4.43355716			

R-Square	CV	Root MSE	ME Mean
0.998085	0.313741	0.046075	14.68577

ANOVA OF PERFORMANCE OF GROWING PIGS

Feed intake

Dependent Variable: Week 1

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	133.3396800	26.6679360	12.60	0.0147
Error	4	8.4641600	2.1160400		
Corrected Total	9	141.8038400			

R-Square	Coeff Var	Root MSE	week 1 Mean
0.940311	7.177842	1.454661	20.26600

Dependent Variable: Week 2

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	180.2705000	36.0541000	146.28	0.0001
Error	4	0.9859000	0.2464750		
Corrected Total	9	181.2564000			

R-Square	Coeff Var	Root MSE	week 2 Mean
0.994561	2.278396	0.496462	21.79000

Dependent Variable: Week 3

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	268.1090600	53.6218120	84.25	0.0004
Error	4	2.5459000	0.6364750		
Corrected Total	9	270.6549600			

R-Square	Coeff Var	Root MSE	week 3 Mean
0.990594	3.329413	0.797794	23.96200

Dependent Variable: Week 4

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	276.8052500	55.3610500	72.43	0.0005
Error	4	3.0572400	0.7643100		

Corrected Total	9	279.8624900			

R-Square	Coeff Var	Root MSE	week 4 Mean
0.989076	3.650458	0.874248	23.94900

Dependent Variable: Week 5

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	293.4398500	58.6879700	49.15	0.0011
Error	4	4.7763600	1.1940900		
Corrected Total	9	298.2162100			

R-Square	Coeff Var	Root MSE	week 5 Mean
0.983984	4.524259	1.092744	24.15300

Dependent Variable: Week 6

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	443.3351300	88.6670260	4013.90	<.0001
Error	4	0.0883600	0.0220900		
Corrected Total	9	443.4234900			

R-Square	Coeff Var	Root MSE	week 6 Mean
0.999801	0.537355	0.148627	27.6590

Dependent Variable: Average daily feed intake (ADFI)

Source	DF	SS	MS	F Value	Pr > F
Model	5	4.95431140	0.99086228	87.32	0.0004
Error	4	0.04538860	0.01134715		
Corrected Total	9	4.99970000			

R-Square	CV	Root MSE	ADFI Mean
0.990922	3.155302	0.106523	3.376000

WEIGHT GAIN

Dependent Variable: Initial weight (IW)

Source	DF	SS	Mean Square	F Value	Pr > F
Model	4	13.2460000	3.3115000	0.16	0.9511
Error	5	104.9700000	20.9940000		
Corrected Total	9	118.2160000			

R-Square	CV	Root MSE	IW Mean
0.112049	11.46053	4.581921	39.98000

Dependent Variable: Week 1

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	225.9175883	45.1835177	31.25	0.0027
Error	4	5.7834117	1.4458529		
Corrected Total	9	231.7010000			

R-Square	Coeff Var	Root MSE	Week 1 Mean
0.975039	3.000839	1.202436	40.07000

Dependent Variable: Week 2

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	323.8369062	64.7673812	76.11	0.0005
Error	4	3.4040938	0.8510234		
Corrected Total	9	327.2410000			

R-Square	Coeff Var	Root MSE	Week 2 Mean
0.989598	2.213845	0.922509	41.67000

Dependent Variable: Week 3

Source	DF	SS	Mean Square	F Value	Pr > F
Model	5	399.4771352	79.8954270	237.28	<.0001
Error	4	1.3468648	0.3367162		
Corrected Total	9	400.8240000			

R-Square	Coeff Var	Root MSE	Week 3 Mean
0.996640	1.341360	0.580273	43.26000

Dependent Variable: Week 4

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	450.5396327	90.1079265	140.99	0.0001
Error	4	2.5563673	0.6390918		
Corrected Total	9	453.0960000			

R-Square	Coeff Var	Root MSE	Week 4 Mean
0.994358	1.797285	0.799432	44.48000

Dependent Variable: Week 5

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	479.4586238	95.8917248	192.04	<.0001
Error	4	1.9973762	0.4993440		
Corrected Total	9	481.4560000			

R-Square	Coeff Var	Root MSE	Week 5 Mean
0.995851	1.553744	0.706643	45.48000

Dependent Variable: Week 6

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	626.3707492	125.2741498	287.12	<.0001
Error	4	1.7452508	0.4363127		
Corrected Total	9	628.1160000			

R-Square	Coeff Var	Root MSE	Week 6 Mean
0.997221	1.398856	0.660540	47.22000

Dependent Variable: Final weight (FW)

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	5	624.4514608	124.8902922	266.56	<.0001
Error	4	1.8741392	0.4685348		
Corrected Total	9	626.3256000			

R-Square	Coeff Var	Root MSE	FW Mean
0.997008	1.450203	0.684496	47.20000

Dependent Variable: Average daily gain (ADG)

Source	DF	SS	MS	F Value	Pr > F
Model	5	15.50771167	3.10154233	360.91	<.0001
Error	4	0.03437477	0.00859369		
Corrected Total	9	15.54208644			

R-Square	CV	Root MSE	ADG Mean
0.997788	7.672115	0.092702	1.208300

Dependent Variable: Feed conversion ratio (FCR)

Source	DF	SS	MS	F Value	Pr > F
Model	5	2652.886982	530.577396	137.94	0.0001
Error	4	15.386270	3.846567		
Corrected Total	9	2668.273252			

R-Square	CV	Root MSE	FCR Mean
0.994234	20.63015	1.961267	9.506800