IDENTIFICATION, QUANTIFICATION AND NUTRITIONAL CHARACTERIZATION OF AGRO-INDUSTRIAL BY-PRODUCTS IN NAMIBIA AS POTENTIAL SUPPLEMENTS OF THE BUSH-BASED FEEDS

A THESIS SUBMITTED IN FULFILMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE (ANIMAL SCIENCE)
OF

UNIVERSITY OF NAMIBIA
BY

Magdalena Ilongeni Kamati

Student Number: 201177676

September 2019

Main supervisor: prof. Johnfisher Mupangwa

Co-supervisor: Dr. Maria N. T. Shipandeni

ABSTRACT

Feed shortage, especially during dry seasons, is a critical threat to livestock production in Namibia. Innovative feed production from encroacher bush species has benefits of increasing fodder availability and controlling bush encroachment. Bush-based feed is characterized by high fiber and low protein content which makes it less palatable and digestible to livestock; hence often requires supplementation with commercial feed ingredients which increase bush feed production costs. This study was undertaken to identify, quantify and characterize the nutritive values of agro-industrial by-products (AIBPs) in Namibia as potential supplements for the bush-based feed. A survey conducted for a period of six months in 2018 (from March to September) targeting agricultural processing companies across Namibia identified a total of ten cereal by-products (sorghum brew residue, pearl millet bran, hominy chop, malt dust coarse, malt dust fine, malted barley, maize chop, wheat bran, traditional spent grains, and industrial spent grains), six oil seed-by-products (marula oil seed cake, olive oil press cake, jojoba oil press cake, !Nara oil press cake, press cake) and four horticultural by-products (potato peels, herb wastes, cull vegetables, and winery and spirits by-products). Cereal by-products can be available throughout the year and majority is sold at a price range of N$0.20-N$2.90/kg. Pearl millet bran and hominy chop had the highest yearly production volumes of about 60 000kg/year. The highest yearly production volume for oil seeds was 2000 kg. Majority of the oil seeds are mainly used as fertilizer and available from April to December. Most of the horticultural by-products are seasonally available, except for potato peels mainly from restaurants which have a year-round production. Chemical compositions, *in vitro* gas production, organic matter digestibility and metabolizable energy of some of the agro-industrial by-products identified were determined. The chemical compositions differed significantly ($p \leq 0.05$) among the cereal and oil seeds by-products categories. The Crude Protein (CP) contents (DM %) of the cereal by-products were in the range of 9 ±0.00 (Sorghum spent grains) to 21.95±0.29 (Brewer's spent grains), while oil seed by-products CP were in the range of 7.55 (Olive (*Olea europaea*) oil cake) to 37.30 ±0.20 (Marula *(Sclerocarya birrea)* oil press) and potato peels had 12.78±0.06% CP. Ether extract for the cereal by-products ranged from 1.37±0.06 (in Malt dust fine) to 9.29±0.06 (Pearl millet bran), 8.11±0.08 (in Manketti (*Schinziophyton rautaneni)* oil cake) to 53.59±0.08 (Marula oil cake) in oil seed by-products while potato peels (the only horticultural by-product analyzed) had 2.06±0.07% EE. Ash content (%DM) of cereal by-products ranged from 2.64±0.04 (Sorghum brew residue) to 5.39±0.02% (in Malt dust coarse) while for the oil seed by-product, the ash content ranged from 2.75±0.05 (Jojoba oil cake) to 5.31±0.00 (in Olive oil cake).The *in vitro* gas production, OMD and metabolizable energy also differed significantly ($p \leq 0.05$) among AIBPs. The organic matter digestibility (OMD) (% in dry matter (DM) basis) of the cereal by-products ranged from 55.55±0.50 (Brewer's spent grains) to 83.50±0.50 (White maize chop) and in oil seed by-products OMD ranged from 38.95±0.15 (Marula oil press) to 59.35±0.15 (Jojoba oil cake). The metabolizable energy (ME) for the cereal by-products ranged from 9.30±0 MJ/Kg (Brewer's spent grains) to 14.00±0.00 MJ/Kg (White maize chop) while for the oil seeds by-products ranged from 7.75±05 MJ/Kg (Manketti oil cake) to 15.95±05 MJ/Kg (Marula oil press) and potato peels had 11.05±0.05 MJ/Kg content of ME. Production volumes and high nutritive qualities of the agro-industrial by-products indicated their potential for utilization as energy and protein supplements for fibrous feeds low in crude protein and energy such as bush based feed in Namibia.

Key Words: Identification, agro-industrial by-products, bush- based feed, bush encroachment, supplements

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
AIBP	Agro-Industrial By-Products
AMTA	Agro Marketing and Trade Agency
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CF	Crude Fiber
CP	Crude Protein
CRD	Completely Randomized Design
DDGS	Dry Distillers Grains with Soluble
DM	Dry Matter
GDP	Gross Domestic Products
Hem	Hemicellulose
MAWF	Ministry of Agriculture, Water and Forestry
ME	Metabolizable Energy
NAB	Namibian Agronomic Board
NDF	Neutral Detergent Fiber
NRC	National Research Center
OM	Organic Matter
OMD	Organic Matter Digestibility
P	Phosphorus

DEDICATION

This thesis is dedicated to my late name sake and great grandmother Magdalena Uutsi.

May her dear soul continue resting in eternal peace

HYMN: 142

ACKNOWLEDGEMENTS

Firstly, it was only by the grace of God Almighty that this thesis was completed. Secondly, I would like to express my sincere gratitude to my main supervisor Prof. John Fisher Mupangwa and co-supervisor Dr. Maria N. T. Shipandeni for their academic guidance during the research and write up of my thesis. I also feel obliged to specially acknowledge Ms. Vonai Charamba for her enormous support and assistance during the analysis of my research data. Gratitude is also extended to the University of Namibia (UNAM) BUSH TO FEED PROJECT for funding my studies and the project research coordinator Maria Luisa de La Puerta for coordinating and facilitating the project activities. Furthermore, I would like to thank Ms. K. Shiningavamwe, Mr. Werner Gawanab and Mr. Ricky Petrus (Agricultural Scientific Officers at the Ministry of Agriculture, Water and Forestry's, MAWF) for their assistance rendered during the laboratory analysis of my samples.

DECLARATION

I, Magdalena Ilongeni Kamati, hereby declare that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

No part of this thesis may be reproduced, stored in any retrieval system, or transmitted in any form, or by means (e.g. electronic, mechanical, photocopying, recording or otherwise) without the permission of the author, or The University of Namibia.

I, Magdalena Ilongeni Kamati grant The University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which The University of Namibia may deem fit, for any person or institution requiring it for study and research; provided that The University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

	Signature	Date
Magdalena I. Kamati	……………………………	…………………………..
(Student Name)		

Certified by:

Prof. Johnfisher Mupangwa	…………………………..	…………………………….
(Main Supervisor)		
Dr. Maria N. T. Shipandeni	……………………………..	……………………………
(Co-Supervisor)		

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Namibia is a semi-arid Southern African country which is characterized by a maximum mean annual rainfall of approximately 270 mm and minimum of 20 mm (Sweet & Burke, 2006), low soil fertility (in terms of clay and nitrogen contents) and high temperatures ranging between 20 ^{0}C and 37 ^{0}C (Sweet & Burke, 2006). Agriculture contributes 5% to the (gross domestic product) GDP of the Namibian economy and livestock production accounts for more than 60% of the agricultural activities (MWAF, 2015). Although agriculture is the backbone of the Namibian economy as it provides needs for food and raw materials for many industries, low and often unpredictable rainfall makes planning and execution of sustainable animal production extremely difficult (Namibia National Farmers Union (NNFU), 2006). Droughts are prevalent in Namibia and limit livestock production due low quantity and quality feeding which is mostly associated with irregular calving and high mortality (NNFU, 2006).

Livestock production is increasingly and globally becoming a challenging activity with current ongoing problems such as climatic change, land degradations, drought, high temperatures, floods (Morton, 2007), depletion of soil quality and lack of water (Pearson and Langridge, 2008). These factors affect the productivity of crops and forage plants, therefore limiting feed resources which have adverse impacts on animal productivity. A challenge therefore presented to animal nutrition scientists is to identify and promote the use of alternative feed resources that have adequate nutritional value and are better adapted to harsh environmental conditions (Food and Agriculture Organization (FAO), 2012).

Livestock production occupies approximately 30% of the global arable land (FAO, 2008) and it plays important socio-economic roles both at household and national levels in Africa by providing the underprivileged rural households with milk, meat, manure, power, and cash (Kosgey *et al*., 2003). However, it is predicted that the world's human population in developing countries will grow by nearly 35% in the next three decades (Lynch *et al*., 2018). This is allegedly attributed to rising living standards in developing countries and therefore expected to contribute to a future increase in the demand for animal products (FAO, 2008). According to FAO (2012) it is expected that from the year 2000 to 2020, the global meat consumption will rise from 233 to 300 million tons and milk will rise from 568 to 700 million tons. The expected rise in demand of animal products will therefore require increased animal productivity (FAO, 2012).

According to Leng (1991) sufficient amounts of protein and energy are mandatory to properly balance forage based diets for ruminants. This is accentuated when low quality forages form a majority of the diet, as it is often the case in dry or in environments with degraded soils (Ball *et al*., 2001). In fact, voluntary feed intake decreases in forages containing less than 7 % crude protein (NRC, 2000). The signs of protein deficiency include lowered appetite, weight loss, poor growth, depressed reproduction performance and reduced milk production (Ball *et al*., 2001; FAO, 2004).

The problems associated with low protein and mineral deficiencies can be addressed by supplementation. As a traditional practice, some Namibian farmers primarily supplement their ruminant livestock (cattle, goats and sheep) with crop residues, indigenous plants pods (*Acacia erioloba*) (Els *et al*., 1999) and baled grass (Namibia Census of Agriculture, 2015) to cope with the challenging dry seasons of limited feed availability.

According to Atuhaire *et al*. (2014), in some developing countries agro-industrial by-products (AIBPs) which often are generated in agricultural activities and food industries are used as alternative feed resources during the dry seasons when forages are low in essential nutrients. Agro-industrial by-products are residues deriving from processing of the main products to manufacture food products for sale (Jeon *et al*., 2016). Several studies have shown the possibility of exploiting AIBPs as alternative feed resources (Ben Salem, 2004; Makkar, 2017). However, AIBPs are yet not extensively used in some parts of the world due to various reasons such as scarcity of information regarding their nutritional value, variability in composition, high moisture content, high handling and transportation costs, competition with other uses, occurrence of anti-nutritional factors and, lack of legislation (Makkar, 2017). Interestingly some studies have showed that many of the AIBPs compared to crop residues, have a low fiber content and/or high energy or crude protein content (Preston, 2007), making them valuable potential supplements to the diets which have high fiber content, medium protein and low energy such as cereal crop residues commonly used during dry seasons.

In arid savanna ecosystems, bush encroachment is considered as a threat to livestock productivity as it reduces the rangeland carrying capacities by suppressing the growth of palatable grasses and herbs (de Klerk, 2004; Ward, 2005; Schröter *et al*., 2009). The condition is considered to be partially a result of inappropriate land management and other factors such as fire regime, browsing pressure, the presence or absence of mega herbivores, frost and other disturbances which play a part in determining the dynamics and the competition between woody species and the herbaceous layer in savannas (Joubert and Zimmermann, 2002). However, according to Ward (2005) factors or mechanisms that promote bush encroachment are not clearly understood and their individual contribution to bush encroachment is still debated.

Bush encroachment has affected Namibia on a massive scale. Reportedly, some 26 to 30 million hectares of the Namibian farming land in 9 regions of the country's 14 regions is affected by bush encroachment (Honsbein *et al*., 2017). The affected area amounts up to approximately 30% of the Namibian's land, lowering the country's rangeland production capacity up to two thirds (Honsbein *et al*., 2017). Kgosikoma *et al*. (2013) and Rothauge (2014) stated that within the challenges of bush encroachment lay enormous social and economic potentials for agriculture and rural livelihoods in general if value is added to the encroacher bush (Kgosikoma *et al*., 2013; Rothauge, 2014). Woody encroacher species can be used at industrial scales for the production of wood products (i.e. charcoal), electricity, building materials and animal feedstuffs which as well have a potential benefit in employment creation (Rothauge, 2014).

Processing encroacher bush biomass (thin branches, twigs and leaves) into animal feed has emerged as one of the promising sustainable value chain addition (Lukomska *et al*., 2014; Honsbein *et al*., 2017). The typical bush-based feed production process in Namibia involves harvesting the encroacher bush biomass and mixing with suitable supplements such as molasses, tannin binding chemicals such as PEG, urea, maize, and cottonseed cake in order to increase the nutritional content, digestibility and palatability of the bush-based feed (Honsbein *et al*., 2017). The supplements are often imported and expensive (Annual Trade Statistics Bulletin, 2016), which increase the cost of bush feed production. The aim of this research study was to identify and quantify, and characterize the nutritional composition and quality of the agro-industrial by-products in Namibia as potential supplements to bush- based feed. The foregoing gaps as presented in the background narrative make the research problem clearer as mentioned in Section 1.2.

1.2 Problem statement

Livestock bush feed production has been thought of to be one of the promising sustainable value addition chain and a tool to control bush encroachment in Namibia (Rothauge, 2014; Honsbein *et al*., 2017). Bush-based feed is characterized by high fibre, and low crude protein content which makes it require supplementations with other feed ingredients in order to improve its protein, energy content and feed intake. Ingredients such as molasses, yellow maize, and urea and cotton seed cake are some of the commercial supplements utilized by some farmers in bush –based feed rations (Honsbein *et al*., 2017). These supplements are however expensive and increase the cost of bush feed production. A reduction in the cost of bush feed production could be achieved if locally available and affordable supplements of better nutrient quality such as agro-industrial by-products were found and utilized.

Even though Namibia host some agro-industries that are involved in processing of crops for flour, starch, beer, oil, wines and spirits productions (Trade Policy Framework, 2016), there is a lack of data and information regarding by-products (AIBPs) these companies generate. That data information includes the by-products kinds and quantities, time of availability, costs, chemical composition, and nutritional values as well as their uses in feed production.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this research was to identify and quantify agro-industrial by-products in Namibia and to determine their nutritional composition and assess their potential as supplements to bush-based feed.

1.3.2 Specific objectives

I) To identify, and quantify cereal grains, oil seeds and horticultural agro-industrial by-products in Namibia.

II) To determine the chemical composition of cereal grains, oil seeds and horticultural agro-industrial by-products.

III) To determine the *in vitro* gas production, *in vitro* organic matter digestibility and metabolizable energy of cereal grains, oil seeds and horticultural agro-industrial by-products.

1.3.3 Hypotheses

I) There are no substantial quantities of cereal grains, oil seeds and horticultural agro-industrial by-products available in Namibia.

II) The chemical compositions of cereal grains, oil seeds and horticultural agro-industrial by-products available in Namibia are similar.

III) The i*n vitro* gas production, *in vitro* organic matter digestibility and metabolizable energy of cereal grains, oil seeds and horticultural agro-industrial by-products products are similar.

1.4 Significance of the study

Namibia is an extensive livestock producing country where ruminant livestock rely mostly on grass and forages for their nourishment. Due to low and unpredictable rainfall patterns and recurrent droughts feed is often scarce. Fodder was ranked 8th most imported goods in Namibia in the year 2016 (Annual Trade, 2016). The search of agricultural by-products to use as supplements in forages and other feedstuff especially during the dry season is imperative to increase livestock survival and productivity. The outcome of this study will therefore contribute to the knowledge and documentation of available local agricultural by-products as potential supplements for livestock feeds.

The identification of by-products as supplements to animal feeds in Namibia will also indirectly provide means to develop an agricultural by-product market which could help local producers to recover production costs from AIBPs while ensuring animal feed security. The incorporation of by-products in animal forage diets could also contribute to the decrease of environmental pollutions caused by their means of disposals. The consideration of utilizing agricultural by-products as supplements to livestock feed in Namibia will also help farmers to engage in alternative feed production which will reduce the competition for cereals between humans and livestock while decreasing the costs involved in feed import.

1.5 Study Limitations

The updated official list for the registered entrepreneurs and local producers in Namibia was lacking. The study was limited to agricultural by-products of plant origin. The number of AIBPs studied for chemical composition analysis and *in vitro* digestibility trial was limited to the agro-industrial by-products available during the time of research study from companies which granted permission for samples collection.

CHAPTER TWO

LITERATURE REVIEW

2.1 Namibian Agriculture

Namibia is rated to have the driest climate in sub-Saharan Africa. It receives a mean annual rainfall of approximately 270 mm with wide regional variation ranging from less than 20 mm in the western Namib and coastal zones to more than 700 mm at the eastern end of the Caprivi strip (Sweet, 1998). Recently in the year period of 2013 to 2014 received low rainfalls and a sebsquent severe drought (Krediles *et al*., 2015). Water supply is limited and the rate of evaporation is very high while soil fertility is low and temperatures are high ranging between 20 ^{0}Cand 37 ^{0}C (Sweet and Burke, 2006). Namibia have total surface area of the 824 292 km^{2} surface area (van der Merwe, 1983; Moorsom, 1984, UNEP (2012)), but 15% of it is not suitable for farming; which account for mainly agricultural unsuitable areas and state owned areas such as nature reserves and diamond mining area; 44% of the total area is farmed commercially and 41% is communal land (Talbot, 1970; Rao *et al*., 1991). Despite low and unpredictable rainfall patterns and poor soils, the agricultural sector remains the backbone of the Namibian economy and the second largest primary industry after mining, with a 5% contribution to gross domestic product (GDP) (Mushendami, 2008, Kerdiles *et al*., 2015). On average, 70% of the Namibian population depends on the agricultural sector for their livelihood (Mushendami, 2008; Bamhare, 2009).

The agricultural sector also contributes significantly to manufacturing, with food processing making up about 2% of the manufacturing outputs. Food and beverage industries have a high percentage of agricultural inputs and represent more than 50% of the manufacturing industries

(NAMTPS, 2011). According to Trade Policy Framework (2016) Namibia's most valuable exports are beverages, spirits and vinegar, fruits and nuts, flour, vegetables and oil seeds. Within the domestic processing industries milling industry is leading and relatively developed. Horticultural products tend to be exported due to insufficient horticultural storage, processing, marketing facilities and logistical service infrastructure in the country (NAMTPS, 2011). The key local agricultural products are livestock (cattle, goats, sheep, pigs and poultry), crops and horticulture (maize, wheat, pearl millet, cabbage, watermelon, potatoes, tomatoes, onion, grapes, dates, mangoes, etc.).

Agricultural products are the key input into food processing industries in Namibia, predominantly livestock that provides multiple derivative products such as meat products, biltong, canned beef, leather products, milk and other dairy products. From the crop products, significant processing activities include milling, pasta production and baking. Many food products are produced on a small scale and a few of them are processed for domestic sales and fewer are exported. High value processing activities are also observed in the cosmetics and medicinal industries (NAMTPS, 2011).

2.2 Livestock farming in Namibia

Namibia is an extensive livestock production country (Els *et al.*, 1999), where numbers of livestock change in response to the amount of rainfall received (Sweet, 1998; Kruger & Lammerts-Imbuwa, 2008). Namibian livestock population's figures for the years 2010 to 2015 in communal and commercial productions are presented in Table 2.1 below. The figures indicate that there have been fluctuations in the livestock populations both at communal and commercial level. Cattle production is the most important livestock related activity followed by small stock (sheep and goats).

In commercial farming systems, livestock is raised under extensive ranching conditions, relying on natural pasture and occasionally supplemented with protein/mineral licks (Els *et al*., 1999). According to Agricultural Statistics bulletin 2010-2015 (2017) sheep are largely concentrated in the commercial sector particularly in the drier south and are mostly the Karakul, bred mainly for pelt, and the Dorper for meat production. In addition, goats are more widely distributed and the main breeds are the Boer and Angora. Ostrich farming is practiced on a small scale in the drier parts of the country. Livestock production in communal areas is mainly confined to the northern part of the country where indigenous Sanga is the dominant breed of cattle.

Table 2. 1. Namibia national livestock census for the year 2010 to 2015.

	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Cattle Total	2389 891	2762 240	2904 451	2634418	2882489	2919 713
Commercial	729 308	804526	874199	826315	860140	873332
Communal	16 60583	19 57714	20 30252	1808103	2022349	204 6381
Sheep Total	1378861	2209593	2677913	2188758	2044156	1973393
Commercial	910334	1825565	2154698	1799259	1670166	1613657
Communal	468527	384028	523215	389499	373990	359806
Goats Total	1690467	17366565	1933103	1693145	1892439	1868535
Commercial	280243	426189	387089	427379	410727	522798
Communal	140 224	1310376	1546014	126566	1481712	1350321
Pigs	63498	43865	69430	184884	68710	277720
Commercial	25487	18447	21750	22839	26418	25 904
Communal	38011	25418	47680	162045	43058	37077
Ostriches	1375	4794	5541	5582	5302	4672
Commercial	1339	4754	5421	5231	5042	4369
Communal	36	40	120	351	300	303
Poultry	777480	684236	940765	659033	3436430	2429529

Source: Agricultural Statistics bulletin 2010-2015 (2017).

2.3 Crop production in Namibia

The main crops produced in Namibia are pearl millet, sorghum, maize, wheat, beans, and some fruit and vegetables such as melons, grapes, potatoes and tomatoes (Agricultural Statistics Bulletin 2010-2015 (MAWF, 2017). At subsistence crop production level, the field size varies from 0.2 to 10 ha, but farmers typically cultivate about 2 to 4 ha (Lechner, 1992; Yaron *et al*., 1992), mainly with pearl millet, sorghum or maize (or a mixture of these grains) and often some minor but very important crops like bambara nut, groundnut, cowpea and melons. The total areas cultivated for major crops (pearl millet and maize) production from year 2010 to 2015 in the Northern communal areas are presented in Table 2.2. The figures in Table 2.2 indicate that there was a fluctuation in the area cultivated from 2010 to 2015 due to poor rainfall received in those years. Larger area (293256 hectares) in 2011 compared to least area (227 643 hectares) in 2012 was planted pearl millet.

Table 2. 2. Total area cultivated for pearl millet and maize production from year 2010 to 2015 in the Northern communal areas.

	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Millet						
Area planted (ha)	**286 351**	**293256**	**227 643**	**249 927**	**276 345**	**238 241**
North Central	262 786	266 143	252 914	225 019	251 039	215 329
Kavango	17 834	19 680	17 565	17 565	18 411	15 659
Zambezi	5 731	7 433	7 164	7 343	6 895	7 253
Maize						
Area planted (ha)	**13 485**	**16 859**	**16 007**	**16 331**	**15 666**	**15840**
Kavango	3 104	3 396	3 031	3 031	3 177	2 702
Zambezi	10 381	5 242	4 554	2 458	2 2232	1 432

Source: Agricultural Statistics Bulletin 2010-2015 (MAWF, 2017)

According to Lechner, (1992) the grain yields of individual household subsistence farmers of pearl millet vary from 100 kg /ha to 900 kg/ha whereas the potential yield in the area under good management, using improved varieties and fertilizer, is 1,200 Kg/ha. The total yields of cereal crops (pearl millet, maize and sorghum) in northern communal areas; namely: Northern central, Kavango and Zambezi for the past few years (2010 to 2015) are presented in Table 2.3. The total yield of pearl millet was higher (81 155 tons) in 2010 and lowest (16 973) in 2015. There was a huge decrease in sorghum yield from 7 883 tons in 2010 to 1671 tons in 2015. The yield of maize in communal areas was higher (6 2860 tons) in 2010 and lowest (1 432 tons), while commercial maize production yield was highest (54 220 tons) in 2010 and lowest (40 170 tons) in 2015.

Table 2. 3. The production of sorghum, millet and maize in communal and commercial areas from 2010 to 2015.

	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Production (Tons)						
millet	81 155	46 891	63 565	26 886	48 294	16 973
North central	75 059	46 891	63 565	26 886	48 294	16 973
Kavango	3 984	4 199	2 935	1 484	3 043	850
Zambezi	2 112	1 850	2 104	1 410	3 091	1 207
Sorghum *	7 883	5 769	7 735	2 191	4 153	1671
Maize total	6 2860	5242	4 554	2 458	5 232	1 432
Kavango	1 396	1 354	1 016	335	774	139
Zambezi	4 860	3 888	3 538	1223	4 458	1 293
Commercial total Production	54 220	68 470	76 991	41 485	76 445	40 170
Rain fed (dry land)	20 045	36 528	36 725	5474	33929	6100
Irrigated	27 919	26 925	35 712	33 553	37 284	32 638

Source: Agricultural Statistics Bulletin (2017)

Namibian vegetation also hosts important wild plant species utilized for food, medicine, oils and other products. These includes wild plant species such as *Tylosema esculentum* (marama beans), wild melons such as *Citrullus lanatus, Ximenia* species, *Acanthosicyos horridus, Schinziophyton rautanenii* and *Sclerocarya birrea* (Kolberg, 1996), *Harpagophytum* species, *Hoodia gordonii*, and *Commiphora wightii* (United Nations Enviroment Programme (UNEP, 2012). These have a potential commercial market as they provide crude extracts from their tissues of which typically contains novel and structurally diverse chemical compounds. According to UNEP (2012) exports of wild plant species derived products amounted about N$ 22.5 to 27 million in 2008. Consumers are increasingly becoming aware of their benefits which are leading to the expansion of their market.

2.4 Bush encroachment in Namibia

Bush encroachment is one of the most important agricultural threats in the arid savanna ecosystems (de Klerk, 2004; Schröter *et al*., 2009). It entails an invasion/thickening of undesired woody species with an associated suppression of the palatable grasses. It also decreases biodiversity and the carrying capacity of the ecosystem (Lukomska *et al*., 2014). In this regard bush encroachment poses a major risk to food security (Bovey 2001; de Klerk, 2004); and threaten the sustainability of both livestock production systems and human well-being (Kgosikoma and Mogotsi, 2013).

Bush encroachments have affected mostly areas in semi-arid savannas with annual rainfall varying from about 30 mm in the west to 500 mm in the north-eastern parts of Namibia (Jourbert and Zimmermann, 2002) consisting of seven vegetation types, namely Mopane Savanna, Mountain Savanna and Thornveld, Thornbush Savanna, Highland Savanna, Camelthorn Savanna and Woodland (Geis,1971). The density of bush encroachment by dominant encroacher species in various parts of Namibia is presented in Figure 2.1.

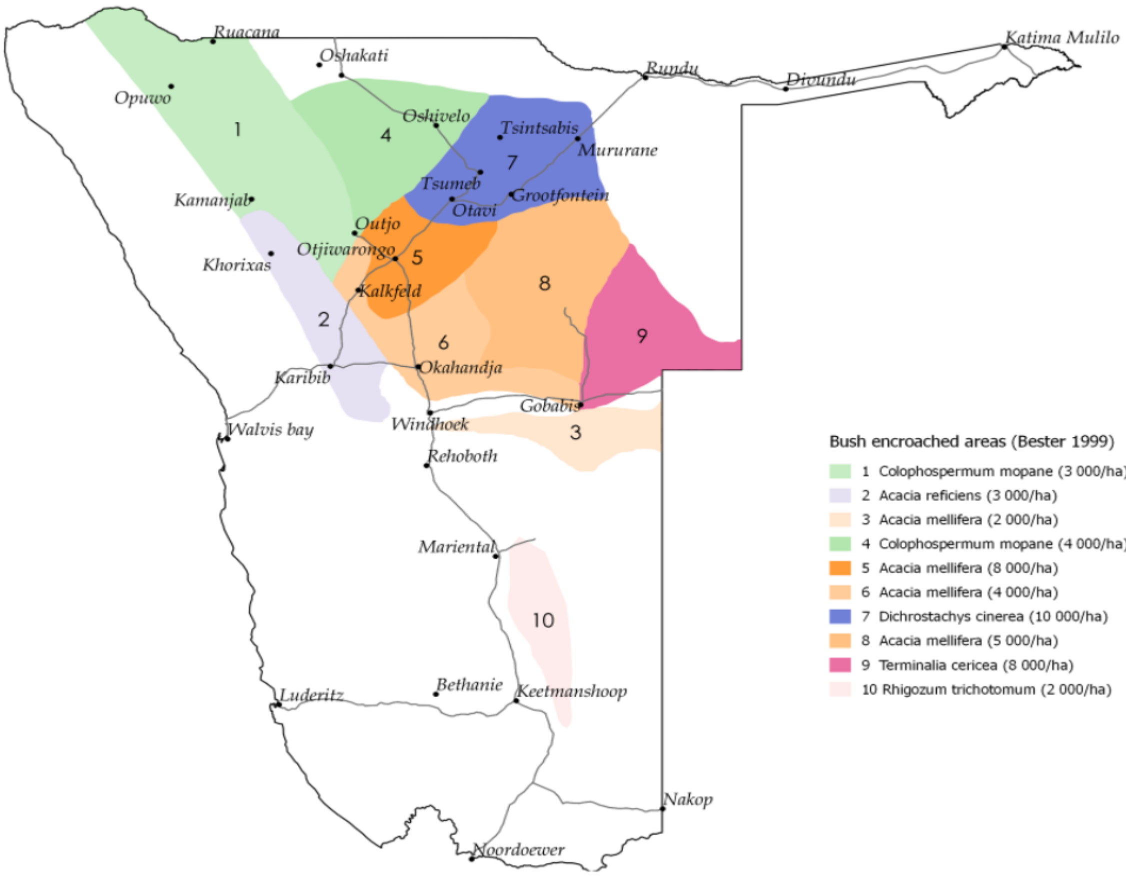


Figure 1 Density per hectare of dominant encroacher bush species in Namibia (Bester, 1999)

On the contrary, woody plant species also play important roles in the rangeland ecosystems. Acacia *mellifera, Acacia erubenscens* and *Acacia hereroensis* support the existence of Marbled Emperor moth (*Henoicha dyops*) (Oberprieler, 1995). Acacia species and *Dichrostachys cinerea* are likely to harbour nitrogen-fixing *Rhizobium* bacteria in the root noodles for soil nitrogen fixation (Jourbert and Zimmermann, 2002) and contribute significantly towards carbon sequestration (Kgosikoma *et al*., 2013). Complete removals of some woody plant species such as *Dychrostachys cinerea* would lead to overall nutrient losses from the soil, since the nutrients locked up in the wood will be removed along with the wood (Jourbert and Zimmermann, 2002). This denotes that bush encroachment requires sustainable methods of control.

2.5 Importance of woody plants in livestock nutrition

Woody plants form a major component of the diet of livestock in the arid and semi-arid zones of Africa, India, Australia, and Southern America (Otsyina *et al*., 2000; Salem and Smith, 2008). Woody plants (i.e. shrubs and trees) parts such the leaves, twigs, flowers, fruits and pods are edible to livestock serve as browse from which livestock animals derive proteins, vitamins and minerals ,mostly lacking in grassland pastures for their nourishment (Marius,2016, Salem and Smith, 2008). Therefore, pastoralists in Africa have established that woody plants contribute significantly towards livestock feeding during the periods of droughts (Kgosikoma *et al*., 2012a) and are essential in reducing the cost of supplementation, yet most grazing policies in Africa do not consider browse, when determining grazing capacity of a particular land (Kgosikoma and Mogotsi, 2013).

Forage tree cultivation systems for such as *Leuceana leucocephala*, and *Gliricidia sepium* has received much attention and promoted in many tropical areas (Devendra, 1993; Moog, 1998; Njarui and Muleithi, 2004). Fodder trees can be browsed or cut and fed as supplements to natural pastures or poor-quality roughages. Cutting fodder trees to feed livestock animals is necessary because it allow them to access the most edible important part of woody plants not directly accessible due to the height of the woody plants (Sanon *et al*., 2007).

According to Topps, (1992) protein content tends to be higher in young leaves and stems than in other parts of the woody plants. The nutritional value in woody plant foliage is also affected by plant stage of growth and season (Topps, 1992). Besides that, Silanikove *et al*. (2001) and Makkar (2003) stated that woody plants contain different levels of anti-nutritional factors which make nutrients unavailable for rumen micro-flora and the animal.

In response to the predominant droughts and bush encroachment in Namibia, a number of farmers are producing bush-based animal feed utilizing predominant woody species such as *Catophractes alexandri* (Gabbabos), *Acacia mellifera/Senegalia mellifera* (Black thorn) and *Dichrostachys cinerea* (Sickle bush) (Honsbein *et al*., 2017). The process of bush-based feed production involves harvesting and milling branches (including leaves) with a diameter less than 2mm and adding supplements such as molasses, Lucerne, maize, *Vachelia erioloba* (Camelthorn) and Prosopis pods, bran and milled prickly pear cladodes. Generally, during summer months the crude protein content of the bush-based feed is above the maintenance level while the digestibility and metabolizable energy is low because of the high indigestible fibre content. For instance during April, *Acacia mellifera*/ *Senegalia mellifera* can have higher protein content of 12.40% DM and metabolizable energy of 6.5 MJ/kg DM compared to 6.47 CP % DM and metabolizable energy of 6.6 MJ/Kg DM dry months of June/July (Honsbein *et al*., 2017).

2.6 Coping mechanisms to sustain livestock during dry season in Namibia.

The nutrient content and availability of the natural pastures fluctuate from year to year and between seasons depending on the amount of rainfall received. Drought condition force farmers to find alternative feed sources in order to reduce the risk of losing their animals. Some farmers make use of crop residues from maize and pearl millet fields however this act is also limited to the amount of rainfall received to support the growth of crops (Els *et al.*, 1999).

Mineral supplementation is also practiced. The typical licks used in Namibia are such as winter lick (mostly phosphate plus maize or hominy chop), summer (phosphate) and production licks. However, communal farmers are reluctant to use them owing to their high costs.

Few communal farmers and commercial farmers can afford to buy supplements feed for livestock; and some resort to collecting tree pods and feeding them to livestock as protein supplements during the dry season (Tshabalala *et al*., 2013). Supplementary feeding is only practiced at a lesser extent in commercial farm settings such as stud breeders, preparation of show animals, and fattening of oxen in order to obtain better grading, higher slaughter masses and ultimately higher incomes per animal. Some farmers also use chemical treatments such as sodium bicarbonate on crop residue straws in order to improve their nutrient values and digestibility (Els *et al*., 1999).

2.7 Agro-industrial by-products

The term agro-industrial by-products (AIBPs) have been defined differently. Fadel (1999) defined AIBPs as products of plant or animal origin derived during harvesting or processing of human food. Whereas Jeon *et al.,* (2016) defined AIBPs as residues derived from agro-industries due to processing of main products in order to manufacture food products for sale. Agro-industrial by-products originate from a variety of primary agricultural production steps such as intensive animal farming, fishery, and processing of crops such as oil seeds, cereals, and fruits (Preston, 2007; Ugwuanyi, 2016). Preston (2007) stated that some AIBPs are usually rich in nutrients such as protein (oilseeds and meals of animal origin) or sugar (molasses, citrus and pineapple pulps) and occasionally in starch (reject bananas, cassava peels) and low in fibre (Preston, 2007) The availability of AIBPs is determined by the crops and type of agricultural processing plants in the country. Their generation is cultural influenced (Abdalla *et al*., 2008), directly proportional to the growth of agribusinesses in a certain country (Jeon *et al*., 2016, Sol *et al*., 2017) and human population growth (Ugwuanyi, 2016).

Most of the global AIBPs are generated by food sector (Tufarelli *et al*., 2013). According to Zentek *et al.* (2014) substantial amounts of agro-industrial by-products are normally disposed in landfills, incinerators or by land application in various parts of the world which pollute the environment and risking the health of both animals and human (Thi *et al*., 2015; Thieme *et al*., 2017). In general, Thi *et al*. (2015) stated that developing countries are facing relatively greater environmental challenges in food waste management than developed countries.

Agro-industrial by-products productions require resources and are associated with some economic and environmental costs (Thieme *et al*., 2017) therefore, recycled into new products which help to minimize environmental pollutions resulting from means of disposal (Ajila *et al*., 2016; Ugwuanyi, 2016). According to Zentek *et al*., (2011) there is an increasing mind shift as from their regard as wastes to raw materials for other productions. AIBPs recycled and reutilized as fuel, fertilizer; microbial fermentations as carbohydrate sources or livestock feeds (Boucqué and Fiems, 1988).

2.8 Classification of AIBPs

Various AIBPs classifications are possible. Agro-industrial by-products can be classified into different categories depending on their origins such fruit and vegetable processing , sugar industry , grain and legume milling , oil industry and distilleries and breweries by-products (Kasapidou *et al*., 2015; Ajila *et al*., 2016) or depending on their nutrient composition such as those high in fibre and low in nitrogen e.g. straws and stalks of cereals and legume haulms, those high in fibre and high in nitrogen such as animal excreta and brewer’, by-products low in fibre and nitrogen e.g. molasses, citrus and pineapple pulp, by-products low in fibre and those high in nitrogen such as oil seeds cakes and meals and slaughter offal (Preston 1986; Ajila *et al*., 2016).

2.8 Role of Agro-industrial by-products (AIBPs) in animal nutrition

Agro-industrial by-products are characterized by their good protein contents (oilseeds and meals of animal origin) or carbohydrates (molasses, citrus, pineapple pulps, reject bananas, and cassava peels) and low fibre content compared to cereal crop residues (Preston, 2007). In developing countries, they play a crucial role by supplying metabolizable energy and crude protein which are the key components in livestock feeding (Atuhaire *et al.,* 2014). Their peak utilization is allegedly reported to occur during dry seasons, when the forages are low in essential nutrients.

Agro-industrial by-products from processing of cereals, pulses and oilseeds, and undersized and/or broken seeds, are mostly utilized either directly by farmers or by the commercial-feed industries (Makkar, 2017), to substitute grains (cereals and oil seeds) which mostly form concentrate feeds. Agro-industrial by-products can also be processed into total mixed rations (Cazzato *et al*., 2011). The use of most common traditional by-products such as oil meals, brans, middling’s, brewers' spent grains, distillers' grains, beet pulp and molasses (Mirzaei-Aghsaghali Maheri-Sis, 2008; FAO, 2012 and Ugwuanyi, 2016) in animal feeding was also not popular some decades ago (Castro and Neto, 2010; Latef and Ahmad, 2015). New by-products are produced as agro- industries grow (Makkar 2017) and in most cases remain the untapped resources and their potential benefits in animal are rarely established (Mirzaei-Aghsaghali and Maheri-Sis, 2008).

The efficiency of AIBPs use depends on chemical and physical properties (Makkar 2017). Actual names of agro-industrial by-products only may fail to provide their accurate description and chemical composition which makes their laboratory evaluations essential (Kasapidou *et al.*, 2015). Evaluation of by-products is important to determine the suitability of each in a variety of settings and also so that characterization of individual AIBPs can be possible (Mirzaei-Aghsaghali and Maheri-Sis, 2008, Negesse *et al*., 2009). The agro-industrial by-products vary due to various factors and this make their continuous nutritional evaluation necessary (Sol *et al*., 2017).

Makkar (2017) affirmed that recycling AIBPs into animal feed has a realistic advantage over other alternatives such as composting, anaerobic digestion, land filling and incinerating which all have an environmental burden. In some countries, feed produced from food waste is certified as 'Ecofeed' because of the environmental benefits and are eligible for a price premium (zu Ermgassen *et al.,* 2016). In addition, Makkar (2017) further stated that the use of by-products in animal feed could only be worthwhile if safety risks associated with origin in raw materials can be minimized and responsibility is therefore taken to maintain safety and integrity by proper handling and storing. However legislation of recycling food waste to animal feed is still lacking in many countries which covers several aspects of feed quality including laboratory analyses (Makkar, 2017).

2.9 Quantification of AIBPs

The knowledge of agro-industrial by-product quantity is critical in defining their importance and use. Levels of agro-industrial by-products generation from industries differ depending on the region and country. The quantities of AIBPs depend mainly on the availability of the raw material and the capacity of the factory (Sanon, 2007). Quality of by-products derived from any given processing also depends on the processing equipment used (Fadel, 1999). Identification and quantification of by-products has been noted as a growing interest in feedstuffs due to the need to understand and monitor environmental wastes in developed and developing countries (Fadel, 1999). However quantification of some AIBPs such as almond hulls, bagasse, beet pulp, and brewer's grains were proven impossible because of lacking standard equivalent availability in the literature to make conversion from processed foods to by-products (Fadel, 1999). On the other hand, quantification of vegetable wastes by-products at wholesale store by Das *et al*. (2018) was possible.

2.10 Factors limiting the utilization of Agro-industrial by-products (AIBPs) in animal nutrition

Although agro-industrial by-products been reported to have several benefits such as being less fibrous, more concentrated, highly nutritious and less costly as compared to crop residues (Preston, 2007; Zaza, 2008); some authors have critiqued adoption of AIBPs into livestock feeding. Chief limitations to the use of AIBPs in animal nutrition relate to animal factors, logistics, anti-nutritional factors, logistics and economic value (El-Boushy and van der Poel, 2001; Kasapidou *et al*., 2015). El-Boushy and van der Poel (2001) pointed out that feeding values of AIBPs is often too low to secure economic animal production and processes for improving the nutritional value of the residues (such as addition of enzymes to enhance digestion of structural polysaccharides, proteins, and degradation of anti-nutrients) are costly too. Another limitation is related to location of processing factories in urban and peri-urban areas which limit their access by farmers residing in rural areas and makes transportation of the AIBPs to the farms expensive (Sanon, 2007; Alniamy, 2017).

In addition, limitations to the use of AIBPs in livestock feeds could be attributed to variation in composition level, quality, inconsistent content of nutritional and/or toxic factors and nutrient components, incidence of pathogenic microorganisms and need for sterilization, bulkiness and high moisture content which necessitates reprocessing such as drying and pelleting (El-Boushy and van der Poel, 2001; Alnaimy, 2017).

Also according to Alniamy (2017), high cost of handling and transportation from the production site to the farm, lack of awareness in farmers about nutritive value of some by-products, lipid rancidity of high lipids by-products during storage especially olive cake limit the integration of agro-industrial by-products in feeding systems of livestock and may contribute for their underutilization especially in developing countries.

2.11 Cereal based by-products

2.11.1 Cereal milling by-products

Cereal processing represents an important part of the food production chain (Papageorgiou and Skendi, 2018). Cereal grains are pre-cleaned and then milled using either dry or wet method of milling. Dry milling entails the separation of the outer fibrous materials and germ from the grain, which are considered by-products of the grain endosperm, this method of milling is used to produce flour and hulls, bran as by-productst (Papageorgiou and Skendi, 2018) .While wet milling involves soaking or steeping the whole grains mainly corn and is used to produce products such as starch, syrup, and oil and the principal by-product produced is gluten meal (Smith, 2007; Papageorgiou and Skendi, 2018).

Cereal milling by-product compositions vary in terms of their nutritional values depending on the cereal type (Freira *et al.*, 2000; Galassi *et al.*, 2004), type and extent of milling ,which result in different proportions of fibrous and non-fibrous carbohydrates (Amaefule *et al.,* 2009), and also differ along with climate and soil conditions where the grains are produced (Wenk, 2001). These all have an influence in the precision of feed formulation.

Cereal brans are some of the major by-products obtained from corn, wheat, and rice flour production (Zilic *et al.,* 2013; Brewer *et al.*, 2014). Bran as described by Coda *et al.* (2015) is the outer layer of cereals which often get discarded during the milling process instead of being used as a food application, due to consumers' sensory expectations and technological drawbacks in the food industry. Frequent corn by-products of dry milling are corn bran, and hominy feed, and their economic disposal is the main concern of the food industry in fulfilling environmental regulations (El Mekawy *et al.,* 2013).

In industrial milling process of maize, bran is the most abundant, low-valued by-product of the in spite of high amounts of polysaccharide content with marginal amounts of lignin (Yadav *et al.*, 2015). Corn bran is produced in yields of 60–70 grams per each milled kilogram of corn, with a total production of 3 ×106 dry tons per year (Rose *et al.*, 2010).

In some developing countries cereal grains like maize, rice and sorghum, little or none of the total production is reserved to boost the energy content in livestock feeds (Ugwuanyi, 2016), therefore AIBPs could be the answer . By-products from cereals processing of grains such as wheat and maize processing are fed to ruminants, most often dairy and beef cattle and monogastrics because they are notably rich in crude protein (Mwesigwa *et al*., 2013). They can be incorporated into manufactured feeds or purchased as commodity feeds for use as separate ingredients. Generally the energy values for the milling by-products are lower and high on protein than the parent grains. Rice polishing and hominy feed provide both energy and protein and have been found to give consistent results in ruminants when combined with molasses and urea (Larson *et al*., 1993).

Cereal milling by-products can be used to complement other by-products in livestock diets, for instance cotton seed cake can be used along with maize bran as additives to the basal diets of non-ruminants (Atuhaire *et al.*, 2014). Bran from wheat is widely used in dairy ruminants and can be incorporated up to 50% of the total grain mixture for young calves (Sindhu *et al.*, 2002). According to Wahlberg (2009) corn gluten feed is best used as a supplement to forage-based feeding programs because it contains little starch and does not reduce the digestibility of the forage portion of the ration like would happen when feeding high starch feeds. High starch grains begin to cause a reduction in forage digestibility when fed at more than 0.5% of body weight of the animal. Thus it truly acts like a supplement rather than as a substitute for forage because it also provides substantial amount of protein.

The chemical compositions (i.e. dry matter, ash, organic matter, ether extract, calcium, phosphorus, crude protein and fibers) of some of the common cereal milling by-products used around the world are presented in Table 2.4. The chemical composition of individual cereal milling by-products is different among authors. Dry matter percentages are highest in millet bran (95.3%) and lowest in hominy (89.9%). The ash content is highest in wheat midling's (6.1%) and lowest in millet bran. Maize hominy has the highest content of ether extract (16.1%) and barley bran has the lowest ether extract content of 0.8%. In literature pearl millet bran was found to be the most protein rich cereal grains milling by-products with 22.0% of crude protein while maize chop was lowest in CP (9.5%). Wheat bran was found to be the most fibrous cereal by-product with an NDF content of 45.01% while maize bran was less fibrous with 11.0%of NDF content. variations in cereal milling by-product chemical compositions reported by different authors can be attributed variations in the cereal type (Freira *et al.,* 2000; Galassi *et al.,* 2004), type and extent of milling, which result in different proportions of fibrous and non-fibrous carbohydrates (Amaefule *et al.,* 2009), as well as climate and soil conditions where the grains are produced (Wenk, 2001).

Table 2. 4. The chemical compositions (%DM) of cereal milling by-products.

By-Product	DM	Ash	OM	EE	Ca	P	CP	NDF	ADF	ADL	Location	Reference
Maize Hominy	89.9	4.1	-	12.2	-	-	11.4	29.1	7.5	-	Tanzania	Asimwe *et al*. (2014)
	-	-	-	16.1	-	-	14.6	22.7	-	-	Australia,	Moate *et al*. (2011).
Maize chop	90.2	3.2	87.0	-	-	-	9.5	29.9	9.3	-	Kenya	Ondiek *et al*.(1999)
Maize bran	-	5.2	-	10.00	_	0.9	12.8	11.0	-	-	Canada	Welker *et al*.(2012)
Wheat bran	-	-	91.4	3.81	0.28	0.90	14.1	45.01	14.28	4.3	India,	Gendley *et al*.(2008)
	91.1	3.9	-	3.7	-	-	14.3	-	13.4	-	Pakistan	Habib *et al*. (2013)
	94.6		86.8	-	-	-		-	-	2.77	U.S.A	Forster *et al*.(1993)
Wheat Midling’s	-	6.1	-	3.0	-	-	16.1	38.1	9.6	3.6	Uganda	Mpairwe *et al*.(2003)
Rice Bran	91.0	1.33	-	1.5	-	-	15.3	-	-	-	Pakistan	Habib *et al*. (2013)
	-	1.77	-	3.0	-	-	20.4	30.2	11.7	4.5	U.S.A	Forster *et al*.(1993)
	92.6	1.51	-	-	-	-	27.0	-	-	-	India	Signh and Mehra, (1988).
	89.0	-	-	-	-	-	10.6	-	-	-	Nigeria	Egbunike and Ikpi, (1990).
Millet bran	95.3	1.4	93.9	-	0.50	0.61	22.0	38.3	-	-	Niger	Abdou *et al*.(2011)
Barley bran	-	3.6	-	0.8	0.05	0.27	9.8	17.2	10.0	8.5	Sweden	Welker *et al*.(2012)

2.11.2 Brewery and distillery factory by-products

Great amounts of grains such as maize, wheat, rye, barley, oats, milo, buckwheat are used in breweries for the production of various kinds of spirits and alcohol (Mirzaei-Aghsaghali and Maheri-Sis, 2008). During brewing process, cereal grains (raw materials) are fermented in order to convert starch in cereal grains or other raw materials to ethanol (Salim *et al*., 2014), which then gives off spent grains, spent hops and yeast, wet distiller grains, and dried distiller's grains with solubles as by-products (Lee *et al.,* 2012; Stefanello *et al*., 2018).

Fermentation of cereal grains during the brewing process cause other nutrients such as protein, fat, fibre, phosphorus and sulfur become more concentrated in the by-products (e.g. spent grains) than in the original grains (Spiehs and Varel, 2009; Salim *et al*., 2014). In particular, Klopfenstein *et al*. (2008) stated that the fermentation makes the spent grains to become approximately three times more concentrated in nutrients such as protein, fat, fiber, phosphorus and sulphur than the original grain.

Nutrient composition of brewing and distilling factory by-products vary depending on the nutrient composition of the parent grain (Penner and Christensen, 2009), the drying method, amount of soluble added, fractionation of particle size and heat intensity used (Schroeder, 2012). Also according to Böttger and Südekum (2017) chemical composition and feeding value of distillers dried grains is also by types of raw material sole or mixture of cereal grains used and ethanol production plant and as some variations can occur between batches from the same plant. The chemical compositions of brewery and distillery factory by-products are presented in Table 2.5.

According to Wood *et al*. (2011) brewery by-products such as distiller's grains present an excellent and potentially lower cost feedstuff than other more traditional feed used mostly in feedlot diets. Distillers' grains have historically been included in animal diets as an energy and protein supplement by replacing a portion of the dietary concentrates (Penner and Christensen, 2000). In addition, due to continuous growth in brewing and distilling industry by-products increased leading in their use extension to monogastrics as an alternative protein for soybean meal (Schroeder, 2012). However, Wood *et al*. (2011) suggested the need of brewery by-products to be studied regularly especially in regions were new varieties of cereal grains are used to suit temperature climates.

The inclusion levels of brewery and distillation by-products in livestock diet are determined by their nutrient composition and nutrient requirements for the animals in question. In ruminants feeding dry distillers inclusion levels are 30-40% growing beef cattle, up to 40% for finishing beef cattle, 30% for lactating dry cows, up to 20% for growing and finishing lamb and 25% for lactating ewes. For monogastrics, the inclusion rates for dry distiller grains are 5 to 8% for broilers and turkeys, 12 to 15% and 10% for fish (Wadhwa and Bakshi, 2016). Examples of brewery by-products and their chemical compositions are presented in Table 2.5.

Spiehs and Varel (2009) cautioned that inclusion of moderate to high levels of dry distillers grains in animal diets lead to excessive of nitrogen, phosphorus and sulfur concentrations which result in reduction of the nutrient utilization. Additionally, Salim *et al.* (2014) particularly indicated that levels of sulfur 6 to10g/kg DM or higher in dry distiller's grains may decrease dry matter intake and average daily gain in beef production.

Table 2. 5. The nutritional composition (% DM) of brewery and distillery by-products

By-Product	**DM**	**Ash**	**OM**	**EE**	**Ca**	**P**	**CP**	**NDF**	**ADF**	**(MJ/kg) Location**	**Reference**
Sorghum DDGs	89.0	4.2		9.8		0.7	34.0	-	-	- U.S.A	Welker *et al*.,(2012)
wheat DDGs	-	-	-	1.68	-	-	29.8	34.8	23.17	- Canada	Penner and Christensen (2009)
	93.0	5.0	-	3.7	-	1.1	51.0	-	-	-	Welker *et al*.(2012)
	94.4	-	92.8	3.8	0.12	1.02	38.8	_	11.4	- Canada	Li *et al*.(2012)
Maize dry distiller grains	95.5	-	95.2	11.5	0.12	1.02	30.2	30.2	10.8	- Canada	Li *et al*. (2012)
Brewer grains	92.3	_	_	10.3	_	_	20.7	49.1	19.16	19.9	Guermah and Maertens (2016)

DDGs=dry distiller's grains

2.12 Oil seed by-products

Over the past decades the world biodiesel production had increased, and soy bean oil dominates the world biodiesel market (Ramachandran *et al*., 2006). The global supply of soybean meal is therefore much greater than that of any other oilseed by-products (Stein *et al.,* 2016). Soy bean meal is used as the standard against which other protein sources are measured (González-Vega and Stein, 2012). According to Soy and Oilseed Blue Book (2015) the global annual production of soybeans is close to 320 million tons, and more than 200 million tons of soy bean meal which is a residue. Normally, oil seeds extraction mostly yields two common solid by-products namely oil press cakes or oil meal. According to Itavo *et al.* (2015) the distinction between press cake and meal is that the press cake is the solids obtained by cold pressing the whole seed while meal is the solid residue remaining after extraction with solvents.

Some of the common oil seed by-products used to feed livestock are such as canola cake, coconut oil cake, cottonseed cake, groundnut oil cake, mustard oil cake, olive oil cake, palm kernel cake, sesame oil cake, soy bean cake, and sunflower oil cake (Dhillon *et al.*, 2016). Chemical composition varies widely between by-products of oil seeds extraction due to variation in growing conditions, the quality of seeds or nuts, and extraction methods (Dhillon *et al*., 2016). Oil cakes can be either edible or nonedible to animals. Edible cakes normally contain high protein content ranging from 15 to 50% (Ítavo *et al*., 2015; Dhillon *et al*., 2016). The examples of oil cakes not edible to animals are such as castor cake, karanja cake, and neem cake. These are mostly used as organic nitrogenous fertilizers because of their good nitrogen, phosphorus and potassium contents (Molina-Alcaide and Yanez-Ruiz 2008; Franke *et al.,* 2009; Mushtaq *et al.*, 2009; Soren and Sastry, 2009).

Press cake and meals are both classified as protein and energy ingredients with high livestock feeding value (Oliveira *et al*., 2007). Their high protein content (shown in Table 2.6) make them suitable for feeding of ruminants, monogastrics and aquatics (Molina-Alcaide and Yanez-Ruiz, 2008; Franke *et al.*, 2009). Chemical composition oil seed by-products also differ between toxic and non- toxic varieties. For instance according to Church and Pond (1979), toxic jatropha seed cake may contain 56.4 % whereas non-toxic varieties 63.8 % crude protein on a dry matter basis. Oil seeds by-products are rich in unsaturated fatty acids that may reduce fiber digestion in the rumen (Alqaisi and Hemme, 2014).

Some oil seed by-products such as olive cake cause refusal therefore included in the diet only in small quantities. In olive cake around 71 % of the nitrogen is associated with the cell walls and is therefore not available for digestion (Molina-Alcaide *et al.*, 2008). In general feeding animals with diets containing more than 32.1% of crude fat can limit the intake and make it difficult to store it for a long period on the farm (Molina-Alcaide *et al.*, 2008). Some of the methods recommended to improve nutritional qualities of oil seeds by-products include autoclaving (Akhtar, 1983; Lee *et al*., 2018) and decortication (Singh and Prasad, 1979). However, Newkirk *et al. (*2003) stated that increased heat treatments of oil seeds during oil extraction of canola and sunflower flower oil reduce the amino acid profiles of the resulting oil cake.

Oil seed by-products are known to be associated with anti-nutrient components, such as lectins and trypsin inhibitors which interfere with protein degradation and absorption from the intestine. Problems associated with anti -nutritional factors in the oil by-products meals can be lighten by fermentations using microbes such as *Aspergillus oryzae*, enzyme treatment or alcohol extraction(Stein *et al.*, 2016). The examples of oil seed by-products used in livestock and their chemical compositions are presented in Table 2.6.

Table 2. 6. Chemical composition (% DM) of oil seeds by-products.

By-product	DM	Ash	OM	EE	Ca	P	CP	NDF	ADF	ADL	Study location	Ref
Canola oil cake	90.0	_	_	_	_	-	33.9	_	_			A
	87.3	6.5	_	20.4	0.58	1.14	-	22.6	20.1		Canada	B
Coconut oil Cake	88.8	_	_	_	_	_	25.3	_	_	_	Canada	A
	90.0	_	_	_	_	_	18.0	12.0	_	_		C
Cotton Seed Cake	90.4	7.0		0.9	_	_	40.3	_	_	_	_	D
	92.9	6.1		6.7	_	_	43.0	42.3	24.5	19.4	_	E
							33.7					
Macadamia nut cake	94.6	3.3		9.01	0.11	0.38	17.6	50.05	39.1	15.1	U.S.A	F
Groundnut oil	91.8	4.61	_	_	_	_	41.7	_	_	_	India	G
cake	90.0	_	_	5.76	_	_	48.6	31.9	_	_	Nigeria	H
Mustard oil cake	89.8	_	_	_			38.5					A
Olive oil cake	88.0	7.0	_	5.7	_	_	9.50	_	48	_	Egypt	I
	93.2	8.3	93.0	3.4	_	_	6.66	62	22.7	12.1	Spain	J
Peanut cake	89.5	6.5	_	9.56			4.08	24.3	_	_	_	A
Palm kernel cake	90.8	_	_	_	_	_	18.6	_	_	_	_	A
	94.3	_	_	_	_	_	14.2	20.2	_	_	Canada	B
Sesame oil cake	83.2	_	_	_			35.6	_	_	_	_	A
Soy bean cake	98.6	5.2	94.8	3.2	_	_	47.7	24.6	_	_		K
Soybean meal	89.7	6.5	_	4.28	_	_	42.8	21.6	11.3	_	Brazil	L
Sunflower	98.1	3.6	96.4	5.2	_	_	12.9	54.70	32.33	_	_	K
oil cake	92.7	7.1	92.0	1.5	_	_	32.1	46.56	_-	_	_	M
Jojoba oil meal	93.1	4.1	_	4.6	_	_	29.1	49.7	25.7	_	_	N
	91.9	3.1	_	3.0	0.9	3.5	_	_	_	_	_	O

Legend:Ref=Reference, A= Kolesarova *et al*. (2011); **B**=Zhou *et al*. (2015); **C=** Ajila *et al*.(2016); D= Habib *et al*., (2014),**E**=Asimwe *et al*. (2012), **F**= Julio *et al*.(2017); **G**=Ghosh and Mandal (2015) ; **H**=Egbunike and Ikpi (1990), **I**=Fadel and El-Ghonemy (2015), **J**= Ferrer *et al*. (2017), **K**=Ítavo *et al.* (2015), **l**=Oliveira1*et al*. (2016);**M** =Irshaid *et al*.(2003), **N**= Nasser (2009) , **O**=Verbiscar *et al*.(1980).

2.13 Horticultural by-products

Horticultural by-products such as those originating from fruit and vegetable processing are some of untapped resources which need development for safe and economically viable process feed production (Mirzaei-Aghsaghali and Maheri-Sis, 2008; Makkar, 2017). For most fruits and vegetables, the production of waste is estimated to be approximately 30% of the processed material (De las Fuentes *et al.,* 2004). Kasapidou *et al.(*2015) particularly indicated that white wine production, red wine production, fruit and vegetable juice production, fruit and vegetable processing and preservation, vegetable oil production, sugar production from sugar beet generates ranges of 20–30, 20–30, 30–50, 5–30, 40–70, and 85% percent of by-products, respectively.

Horticultural by-products such as peels, seeds, stems, stones, pulp as well as rejected fruits and vegetables differ in chemical composition owing to differences in their physical states, processing technology of the raw material, storage and handling (Bampidis and Robinson, 2006). For instance tomato skins contain high lycopene content than seeds and tomatoes peeled mechanically with sodium hydroxide increases the sodium content of tomato skins (Kasapidou *et al.,* 2015).

Fruit and vegetable processing residues have traditionally been used in animal nutrition as the main feed ingredients (Bampidis and Robinson, 2006). According to Alnaimy *et al.* (2017) horticultural by-products can be utilized while fresh, processed into silage, or dried. Supplementation levels of horticultural by-products differ with the type of animals. For example solid residue that remains after fresh fruits are squeezed into juice called citrus pulp is made up of residue of peel, pulp, oranges, grapefruit and other citrus fruits can used as a source of energy for beef cattle and heifers and up to 45% in calf rations (Alniamy *et al.,* 2017).

Production of juices from fruits also yields a residue called molasses which is produced from the press liquor. According to Alnaimy *et al*. (2017); this molasses is sometimes added back to the pulp during the drying process or used as fermentation substrate in beverage alcohol industries. Common horticultural by-products examples are such as apple pomace (a by-product of cider or juice production from apples), grape marc (a by-product of wine industry after juice has been pressed out), and also tomato pomace (a residue consisting of tomatoes peels and seeds, given off in the production of tomato paste, the tomato juice and puree (Mirzaei-Aghsaghali and Maheri-Sis, 2008).

Eliyahu *et al*. (2015) stated that enormous quantities of horticultural by-products such as pomegranate pulp, avocado pulp, and others are produced from manufacturing grape wineries, avocado oil and fruit juice industry. These by-products or residues usually contain a lot of moisture, are fibrous, and may contain readily fermentable soluble sugars or protein, resulting in spoilage under aerobic conditions; which produce unpleasant odors and create environmental nuisances (Mirzaei-Aghsaghali and Maheri-Sis, 2008, Eliyahu *et al*., 2015). Disposal of these wet by-products by drying or burying is not cost-efficient (Eliyahu *et al*., 2015). The chemical compositions of some horticultural by-products used in livestock feeding are presented in Table 2.7.

Table 2.7. Chemical compositions (% DM) of horticultural by-products

By-product	DM	Ash	OM	EE	CP	NDF	ADF	Location	References
Cassava peel meal	92.03	7.06		0.65	5.7	_		Ghana	Osei and Twumasi (1987)
	88.80	2.00		0.65	5.98	_	-		Eshiett and Ademosun (1981)
Grape pomace	_	2.41		10.26	1.38	32.5	-	Spain	Goñi *et al*. (2007)
Citrus pulp	92.1	_	92.4	2.5	8.1	-		Portugal	Moura˜o *et al*. (2008)
	85.36	3.17	-	3.78	8.25	10.82	-	Egypt	Alaniamy *et al.* (2017)
Avocado pulp	18.6	5.50	-	18.2	14.7	65.2	-	Israel	Eliyahu *et al.* (2015)
Grape pulp	42.1	8.67	-	11.3	12.2	61.3	-	Israel	Eliyahu *et al.* (2015)
Potato Peels	98.1	_	_	_	8.25	_	_		Whittemore (1977**)**
	-	6.22	_	5.0-	12.3	41.0	6.30	S.A	Ncobela *et al*. (2017)
	42.49	9.01	_	21 0.26	10.81	70.76	26.36		Negese *et al*. (2016)
Grape fruit pulp	90.91	5.87	-	2.38	9.14	16.66	13.09	-	Lashkari and Taghizadeh (2015)
Lemon pulp	87.10	5.46	-	3.46	9.54	16.69	15.13	-	Lashkari and Taghizadeh (2015)
Lime pulp	90.52	8.12	-	2.75	8.16	17.49	14.53	-	Lashkari and Taghizadeh (2015)
Orange pulp	89.33	5.51	-	3.45	5.50	17.74	11.95	-	Lashkari and Taghizadeh (2015)

2.14 Digestibility of agro-industrial by-products

The ability of a feed to sustain animal performance depends mainly on its digestibility. According to Saha *et al.* (2017) feed digestibility is defined as the measure of extent to which a feedstuff is absorbed in the animal body as it passes through an animal's digestive tract. Several Agro-industrial by-products'digestibility have been investigated by different authors such as Gizzi *et al*., 2001; Crawshaw *et al*., 2004; Hamid et *al*., 2007; Habib *et al*., 2011; Kumar *et al*., 2015, etc, who evaluated the digestibility of cereal by-products, Hamid *et al.*, 2007; Ayadi *et al*., 2013; De Morias *et al*., 2015, etc, who evaluated the rumen *in vitro* digestibility of oil seed by-products as well as authors such as Eliyahu *et al*., 2012; Lashkari and Taghizadeh 2015, and Negese *et al*., 2016 who evaluated the digestibility of horticultural by-products.

2.14.1 *In vitro* digestibility of cereal byproducts

The *in vitro* (DM) and organic matter (OM) digestibility of some of the cereal by-products normally used in livestock feeding are presented in Table 2.8. The table also shows *in vitro* gas production volumes of the cereal by-products after 24 hours of incubation in the buffered rumen fluid. The kinetics of gas production depends on the relative proportions of soluble, insoluble but degradable and undergradable particles of the feed (Getachew *et al*., 1998). Cereal by-products have variable OM digestibility, *in vitro* GP and metabolizable energy contents. This is due to the fact the capability of digestive enzymes to colonize and digest the feed particles is influenced by feed chemical composition (carbohydrate, protein and fat content) and physical (particles size) characteristics have an influence in (Kitessa *et al*., 1999). However, the degree of correlation between *in vitro* gas and digested OM is influenced by various factors such as different equipment, differences in protocol, feed ,inoculum characteristics, which all alter release of gas from the medium (Tagliapietra *et al*., 2010). As indicated in Table 2.8, potale syrup a by-product of alcohol brewing have the highest in vitro OMD potential of 89-93% DM while wheat bran have the highest metabolizable energy value of 16.89 MJ/kg.

Table 2. 8. The *in vitro* DM and OM digestibility, gas production (GP at 24 hours) and metabolizable energy of the cereal by-products

Cereal by-product	DMD (%)	OMD (%)	GP at 24 h (ml/200mgD)	ME (MJ/kg) DM	Reference
Draff	_	50-54	_	9-12	Crawshaw, (2004)
Potale syrup	_	89-93[i]	_	_	
Malt distiller's Dark grains	_	65-69	_	12-13	Gizzi *et al*.(2001)
Wheat bran	_	51.2[i]	-	16.89	Habib *et al*. (2011)
	_	68.5[iv]	27.4	11.5	Hamid *et al*. (2007)
	_	_	48.99	_	Kumar *et al*. (2015)
Rice bran	_	62.0[iv]	_	_	Habib *et al*. (2011)
	62.82[iv]	60.28[iv]	42.65	7.41	Kumar *et al*. (2015)
	_	_	_	6.7	Kumar *et al*. (2015)
Rice hulls	_	37.0[iv]	-	7.41	Habib *et al*. (2011)
Brewers grains	-	60.0[iv]	-	-	Habib *et al*. (2011)
	-	_	-	15.7	Moate *et al*. (2011)
Hominy meal	_	_	_	16.6	Moate *et al*.(2011)

Legend: *iv =in vitro*, *i=in vivo*

2.14.2 *In vitro* digestibility of oil seeds by-products

Extraction methods have effects on the chemical composition of the resulting by-products and determine their nutritional values including digestibility (Lee *et al.*, 2018; Dhillon *et al.*, 2016). This is can be explained by the variation of nutrient composition of oil seeds which are determined by plants growth factors such as water and mineral concentrations (Colombo *et al*., 2010; Ítavo *et al*., 2015). Additionally, individual chemical components and structural features also affect microbial degradation of oil seed by-products (Souza *et al.*, 2009).

The nutrient digestibility of oil seeds by-products varies as reported by various authors. According to Lee *et al*. (2018) DM, CP, EE, Ash, ADF, and NDF digestibility of cold pressed canola cake was 918, 318, 226, 60, 167 and 232 ,g/kg (on DM basis) respectively. While for the solvent extracted canola cake the digestibility of DM, CP, EE, Ash, ADF, and NDF were 890, 451, 150, 85, 201, 398 g/kg on DM basis respectively (Lee *et al*., 2018). Nefzaoui (1991) reported overall dry matter digestibility of 32% DM of olive cake in rumen liquor which is lower than 37% or 42% reported by Molina-Alcaide *et a*l. (2008) and Álvarez-Rodríguez *et al*. (2009), respectively. Álvarez-Rodríguez *et al*. (2009) reported the lowest 12% DM digestibility of olive oil cake. Nefzaoui (1991) concluded that effective nitrogen degradability was 44% in the olive cake and this could be attributed to their high NDF and ADF content. The nutritive values appear to be higher in crude olive oil cake than in the defatted cake (Álvarez-Rodríguez *et al*., 2009).

The ruminant *in vitro* digestibility of amino acids in olive cake is reported to be higher, ranging from 75 to 90% than that of crude protein which commonly fall in the range of 45 to 56 % (Nefzaoui, 1991; Molina-Alcaide *et al*., 2008). The low digestibility of olive cake is also attributed to its high oil content which reduces rumen fermentation by increasing fat and free fatty acids content and its high polyphenol and lignin content inhibits fermentation (Sansoucy *et* *al*., 1985; Zaidi *et al*., 2008; Álvarez-Rodríguez *et al*., 2009). In general press cakes from seeds without hulls have high *in vitro* dry matter digestibility (Souza *et al*. (2009)

The study by Nasser (2009) on the effect of replacing cotton seed meal with jojoba meal on the gas production, rumen fermentation, and true dry and organic matter digestibility at 6%, 9% and 18% levels in a concentrate diet indicated that an increase of cumulative volume of gas by increasing jojoba meal in the concentrate and further indicated that level 6% of replacement had the highest level of gas accumulation 17.20, 25.97, 35.43, 42.83, 48.10 (ml/200 mg) after 12, 24, 48, 72, 96 hours of incubation, respectively.

Itavo *et al*. (2015) recorded greater variations of in dry matter, neutral detergent fibre and acid detergent fibre digestibility of whole oil seeds and their by-products. For example, sunflower, soybean and physic nuts whole seeds had 617.7, 876.0, 453.5 g/kg DM of in vitro dry matter digestibility respectively. Presence of anti-nutritional compounds, such as phenolic, in sunflower seeds (Canibe *et al.*, 1999) and physic nut (Souza *et al.*, 2009), decrease in vitro dry matter digestibility and protein synthesis by rumen microorganisms.

Some of the oil seeds by-products such as Jatropha seed cake processed from *Jatropha curcas L*. are believed to have nutrients content similar to that of soybean seed cake but their use in livestock feeding is limited due to presence of anti-nutritional factors such as phorbol esters, trypsin inhibitors, lectins and phytate which restrict their uses in feed application (Widiyastuti *et al.*, 2015). Therefore treatment methods are employed to alleviate the effects of anti- nutritional factors. Digestibility of jatropha kernel meal was similar to that of toasted soya bean meal (90 %) after having been treated with pepsin. Makkar and Becker (2009) reported that the *in vitro* gas digestibility and metabolizable energy of heat treated soy bean kernel meal at 121 ^{o}C, for 30 min was 78 to 88% and 11 to 13 MJ/kg which are both lower than those for soya bean meal. A decrease in phorbol ester and antitrypsin was achieved through post fermentation of the concentrate protein from Jatropha seed cake using *Lactobacillus acidophilu*, *A.oryzae*, *Lactobacillus acidophilus* (Munarso, 2010; Widiyastuti *et al.*, 2012).

Similarly the multi-enzyme supplementation improved the *in vitro* dry matter digestibility for cold pressed canola cake and solvent extracted canola meal and this could be attributed to hydrolysis of fiber in the canola co-products, thereby increasing the availability of nutrients for digestion by gastric and pancreatic enzymes (Lee *et al.,* 2018). Also the multi-enzyme supplementation increased fiber digestibility in canola meal-based diets (Meng and Slominski, 2005). The cold canola press cake contained less CP, ash, ADF, NDF but more EE than solvent extraction canola meal. The fermentation of cold canola press cake was lower than that of solvent extraction canola meal as evidenced by the lower cumulative gas production. The lower fermentation of cold canola press cake could have been mainly due to lower availability of fermentable substrates.

In vitro and *in vivo* digestibility of dry matter, organic matter, *in vitro* gas production after 24 hours of incubation, and metabolizable energy values of some of the widely utilized oil seed by-products in livestock feeding are presented in Table 2.9.

Table 2. 9. The *in vitro* DM and OM digestibility, gas production (GP at 24 hours) and metabolizable energy of the oil seed by-products

Oil seed by-product	DMD	OMD	GP at 24 ml/200mgDM	ME (MJ/kg DM)	Reference
Olive oil cake (*Olea europaea*)	48.4[*iv*]	41.8[*iv*]	_	_	Ayadi *et al*. (2013)
Soybean meal	80.89[*iv*]	77.1[*iv*]		13.4	Hamid *et al.* (2007)
(*Glycine max*)	80.67[iv]	78.53[iv]	50.96	9.24	Kumar *et al*.(2015)
	86.50				Itavo *et al*. (2015)
Cotton seed cake	59.56[*iv*]	_	_	_	De Morias *et al*. (2015)
(*Populus deltoides*)	64.72[iv]	66.70[iv]	45.31	7.71	Kumar *et al.* (2015)
				6.9	Sherasia *et al*. (2015)
Castor oil cake	49.71[*iv*]	_	_	_	De Morias *et al*. (2015)
(*Ricinus communis*)					
Sunflower oil seed cake (*Helianthus annuus*)	46.31[*iv*]	_	_	_	De Morias *et al*. (2015)
	58.23[iv]				Alves *et al*. (2015)
Canola oil cake (*Brassica napus*)	68.90[iv]	_	_	_	Aderbal *et al*.(2015)
Groundnut cake	69.52[iv]	71.98[iv]	43.08	9.44	Kumar *et al*.(2015)
(*Arachis hypogaea*)					
Mustard oil cake	66.24	69.80	45.31	9.21	Kumar *et al*.(2015)
(*B. juncea (L.)*)					

Legend: *iv=in vitro, i=in vivo*

2.14.*3* *In vitro* digestibility of horticultural by-products

The *in vitro* and *in vivo* digestibility of DM and OM, *in vitro* gas production after 24 hours of incubation, and metabolizable energy values of some horticultural by-products are presented in Table 2.10.

Table 2. 10. *In vitro* (^{iv}) and *in vivo* (^{i}) DM and OM digestibility, gas production (GP at 24 hours (ml/200mgDM)) and metabolizable energy (MJ/kg DM) of horticultural seed by-products

By-product	DM(%)	OM (%)	NDF (%)	GP	ME	Reference
Aspergillus residue	_	85.0%^{i} 90.0^{iv}	97.0^{i} 95.0^{iv}	_	_	Eliyahu *et al*. (2012)
Pomegranate pulp	_	44.0^{i}	–	_	_	Eliyahu *et al*. (2012)
	69.6^{iv}	65.0^{iv}	34.0^{iv} 20.0^{iv}	_	_	Eliyahu et al. (2015)
Grape pulp	—	30.0^{i,} 36.0^{iv}	14.0^{i} 12.0^{iv}			Eliyahu *et al*. (2012)
Avocado pulp	—	43.0^{i,} 29.0^{iv}	21.0^{i} 31.0^{iv}	_	_	Eliyahu *et al*. (2012)
Grape fruit pulp	86.60^{iv}	_	_	_	_	Lashkari and Taghizadeh (2015)
Lemon pulp	89.50^{iv}	_	_	_	_	Lashkari and Taghizadeh (2015
Lime pulp	89.70^{iv}	_	_	_	_	Lashkari and Taghizadeh (2015
Orange pulp	84.10^{iv}	_	_	_	_	Lashkari and Taghizadeh (2015
Potato Peels	48.19^{iv}	77.71^{iv}		25.5	5.01	Negese *et al*. (2016)

Legend: *iv=in vitro, i=in vivo*

2.15 Feeding and performances of livestock on agro-industrial by-products

The practice of feeding AIBPs to livestock animals is an old concept. Feed production companies have utilized by-products in commercial concentrates as sources of nutrients for years. However even though a lot of by-products have been utilized for ages others are relatively new (Benard, 2017).

The primary purpose of considering by-products feed is mainly centered on reduction of feeding cost. This is because feed is the primary cost of achieving livestock production goals such as growing replacement heifers, milk and meat production. In order to establish the by-product value comparison of energy and protein content with corn and soybean, the standard energy and protein livestock feed sources is essential.

2.15.1 Performance of livestock animals fed with cereal grains byproducts

2.5.1.1 Ruminant Animals

In vivo experiments are often conducted to evaluate the by-products effects on livestock performance through supplementation, substitution, replacement of the common feed ingredients in the rations. These enable optimum inclusion levels of the by-products to be determined. Various studies have evaluated the potentials of various by-products as alternative energy feed sources of maize, which is a major worldwide energy source in the diet of livestock.

According to Asimwe *et al.* (2015) the results of finishing feedlot Shorthorn Zebu cattle with diets based on either molasses and maize grain combined with maize or rice by-products which disclosed a greater total daily dry matter intake in molasses based diets i.e. rice polishing with+ molasses (7.64 kg/day) and hominy feed + molasses (7.35kg/day) as compared to maize grain based diets i.e. rice polishing with maize meal (6.94 kg/kg). Energy intake was also higher in molasses based diets, i.e. hominy feed and molasses (86MJ/day) and lowest in the diet of rice polishing with maize meal (69 MJ/day). Hominy feed with molasses finisher diets had the highest daily weight gain (919 g/day), total weight gain (83 kg), final live weight (283 kg), empty body weight (268 kg) and hot carcass weight (151 kg) compared to maize grain based diets.

Cereal milling by-products could be used to supplement fibrous feed materials in order to increase their ruminant's energy intakes. However, according to Benard (2017) cereal by-products such as rice bran, wheat bran and wheat middling's are commonly limited to less than 25 % incusion of the ruminant rations due to their poor palatability, while others like hominy feed limited due to concentrations high concentrations of fat. Mpairwe *et al*. (2003) studied the effects of lablab hay and graded levels of wheat bran supplementation. The dietary treatments comprised of maize/lablab stover + 10.5%wheat bran, lablab hay or ad libitum oats/vetch hay+ 10.9% wheat, each supplemented with 0, 1.25, 2.50, and 3.75 kg DM of wheat bran.

The combination of wheat bran and lablab hay as supplements to cows fed on maize/lablab stover and oats/vetch hay basal diets significantly improved DM digestibility which subsequently increased total DM intake and milk yield both by 21%. A linear increase with a mean increment of 1.09 kg milk per kg increase of wheat bran DM intake was recognized. Milk fat total solids for the cows fed maize/lablab stover increased simultaneously however the increases were not significant for oats/vetch hay-based diets. It was concluded from this study that for optimum milk production, cows fed maize/lablab stover basal forage should be supplemented with 2.5 kg DM/head/day of wheat bran in addition to 0.5% wheat bran and lablab hay while for cows consuming oats/vetch hay forage should be supplemented with a combination of 2.5 kg DM/head/day of wheat bran and 0.9% wheat and bran lablab hay.

Ondiek *et al*. (1998) evaluated the effects of supplementing Gliricidia and maize bran to crossbred (Toggenburg x Saanen) dairy goat kids fed Rhodes grass (*Chloris gayana*) hay as a basal diet ad libitum. The intake of hay was 474 g/day for hay alone, the control diet, while for the supplementation of gliricidia, glricidia plus maize bran (1:1), and maize bran were 504, 455, and 437 g/day respectively. The live weight gains were highest in goats supplemented with a mixture of Gliricidia and maize bran diet (69 g/day) and lowest for the control Rhodes hay only (26 g/day). It was concluded that Gliricidia forage is better utilized when fed with an energy source such as maize bran.

According to Penner and Christensen (2000) and Benard (2017) brewing industry by-products such as brewer's grains and maize gluten meal are regarded as good quality protein livestock feed sources. Brewer's by-product also contains high concentrations of sugars, processed carbohydrates or fats which contribute to energy dietary concentrations (Klopfenstein *et al*., 2008). The effects of feeding corn (*Zea mays*) or sorghum (*Sorghum bicolor*) dried distillers grains plus solubles in growing and finishing diets on growth performance and carcass traits were investigated in beef steers by Wood *et al*., (2011). Control diet contained soybean meal, a diet containing 200 g/kg (DM basis) corn dried distillers' grains plus solubles and a diet containing 200 g/kg (DM basis) sorghum dried distiller's grains plus solubles. After 28 days of feeding trial average daily gain was similar for all the diets. Specifically, 1.56 kg/d±0.04 was reported for control, 1.54 kg/d±0.04 for corn dry distiller's grains solubles, and 1.51 kg/d±0.04 for sorghum dried distiller's grains plus solubles. There was a lower gain in the growing phase for sorghum dried distiller's grains plus solubles compared to corn dried distillers' grains plus solubles. However, fewer days on feed were required for sorghum dry distiller's grains to reach the target back fat for slaughter than corn dry distillers grains with solubles and control.

2.15.1.2 Non- Ruminant Animals

Maize gluten meal which is a by-product of corn milling is a high protein ingredient that is primarily used in diets for ruminants, but its protein quality is relatively poor for monogastrics animals (Almeida *et al*., 2011). Maize germ meal (a by-product of oil extraction from maize) is often utilized in diets for gestating sows, but unlike some other ingredients, the concentration of metabolizable energy of maize germ meal fed to gestating sows is not greater than for growing pigs (Lowell *et al.*, 2015). Maize gluten feed is believed to contain a number of product streams from the wet milling industry and the nutrient concentration, therefore, is more variable than that of other maize co-products. Hominy feed can, therefore, be used as a substitute for maize in diets for pigs, and the concentration of metabolizable energy in hominy feed is comparable to that in maize (Almeida *et al*., 2011; Rojas *et al*., 2013).

Maize bran can be produced from both wet and dry milling industry, but has generally little use in diets fed to pigs (Liu *et al*., 2014). Low-fat maize germ meal may be used in diets for growing and finishing pigs by up to 30% without changing animal growth performance (Lee *et al*., 2012). For the remaining maize co-products, there are limited data on optimum inclusion levels in diets for weanling, growing, or reproducing pigs (Stein *et al*., 2016).

Wheat by-product may be included in diets fed to weanling pigs by up to 20% if diets are formulated to similar concentrations of amino acids and net energy (Garcia *et al*., 2015). However feeding 10 or 20% wheat middlings to growing-finishing pigs may reduce growth performance and dressing percentage of pigs (Salyer *et al*., 2012). The inclusion of wheat distiller's grains with solubles in pig's diets is not worthwhile because its inclusion until 20 to 40% reduce growth performance of growing-finishing pigs.

Distillers dried grains with solubles (DDGS) may be included in diets fed to all categories of pigs by up to 30% without impacting growth performance of pigs (Stein and Shurson, 2009), although fat deposits of finishing pigs may contain more unsaturated fatty acids if DDGS is used in the diets. Whereas 40 or 50% inclusion of maize DDGS in diets fed to lactating sows may result in reduced feed intake and reduced litter performance (Greiner *et al*., 2015). Information about inclusion rates for sorghum DDGS is very limited, but it is believed that up to 30% may be included in diets fed to growing-finishing pigs and reproducing sows (Fioli *et a*l., 2007; Tokach *et al*., 2012).

Dry distiller's grains with solubles have a lower amino acid digestibility in poultry compared to the parent grain. The reason for this variation in amino acid digestibility is most likely due to the effect of the different processing and drying techniques involved in the production of dry distiller's grains with solubles, and intrinsic chemical composition of the material. In general, protease has been primarily used in combination with other enzymes to improve performance of broiler chickens.

Feed intake and body weight gain of the male broiler chickens were increased by inclusion of 150 or 300 g dry distiller's grains with soluble/kg diet sorghum distillers grains with solubles to the diets independent of the enzyme (Barekataina *et al*., 2013). It is possible that the differences in responses to feeding wheat dry distillers grains with solubles was caused by reduced digestibility of lysine and other amino acids, because some sources of the dry distillers by-products may be over-heated during production, which results in reduced of amino acids

(Cozannet *et al.*, 2010). However, rice hulls contain mainly lignin and silica and has no nutritional value (Stein et al., 2016) and rice hulls is therefore not included in diets fed to pigs.

Corn dry distiller's grains are a good source of protein, vitamins, and minerals for poultry .It can be used in balanced diets as a partial replacement for soybean meal and cereal grain in feed for broiler chickens and laying hens without harmful influences on performance indices. Swiatkiewicz *et al*. (2014) evaluated the effects feeding broiler chickens with isocaloric and isonitrogenous diets containing120g corn DDGS (starter phase) or 180g (finisher phase) corn DDGS/kg in a 6 weeks experiment. The inclusion of DDGS into the diet had no effect on growth performance at 21and 42 days of age and breast meat proximate composition, but negatively affected apparent digestibility of dry matter and organic matter, metabolizable energy content of the diet. Inclusion of DDGS also increased chicken breast percentage of linoleic acid and total poly unsaturated fatty acids, and decreased the content of palmitic, stearic acid, saturated fatty acids.

2.15.2 Livestock performance animals fed with oilseeds by-product feeds

2.15.2.1 Ruminant Animals

Several studies have shown that some oil seed by-products can potentially replace soybean meal which is a standard protein source in livestock feeding. In addition, the required protein levels were achieved without compromising the livestock performances. Although oil seeds by-products are known to be good sources of energy, protein and fiber, they might contain greater levels of ether extracts (fat) which interfere with the fiber digestion and normal rumen functions. de Oliveira et al., (2016) evaluated peanut cake as a replacement for soybean meal in the diet of castrated and fistulated Holstein × Zebu steers. The diets were composed of Tifton hay and ground corn with peanut cake at 0, 25, 50, 75, and 100 % levels as a replacement for soybean meal in the concentrate. Intake (kg/day) of dry matter, neutral detergent fiber, and crude protein were not affected by peanut cake supplementation; however ether extract intake increased linearly with the level of peanut cake in the diet. The digestibility of dry matter showed a quadratic effect and there was no effect of replacing soybean meal with peanut cake at all levels on metabolizable energy intake and net energy, ammonia nitrogen, rumen pH, plasma urea, and glucose concentrations. Recommendation is that replacing soybean meal in the concentrate with peanut cake can be made up to 40 % without adverse effects on productivity.

Wyngaard *et al*. (2014) investigated the effect of including palm kernel expeller as partially substitute of the maize and soybean at 0, 200, and 400 g/kg levels in the dairy concentrates of multiparous Jersey cows. The cows were fed for a 60 days period, preceded by 21 days of adaptation. Milk yield and milk fat content did not differ between treatments and were 21.3, 21.3 and 20.7 kg/cow/d and 46.3, and 46.5, and 46.6 g/kg milk fat for the control, low palm kernel and high palm kernel treatment, respectively. Milk protein, milk urea nitrogen, body weight and body condition score did not differ between cows on all treatments. It was concluded that palm kernel expeller can sustain milk yield and milk fat components at a level of up to 400 g/kg of concentrate when fed at 6 kg/cow/d to cows grazing kikuyu-rye grass pasture. However, due to potential palatability problems and a slow rate of intake when fed during milking in the parlour, a recommendation might be to limit palm kernel expeller to 200 g/kg of concentrate.

Replacing cereals and soybean with the combination of sugar beet pulp and rape seed meal, or distiller's grains in a concentrate feed and of dairy cows by Karlsson *et al*. (2017) indicated that silage intake (13 kg of dry matter/d) and milk production (33 kg of energy-corrected milk/day) were not affected by the change in diet. Therefore, replacing cereals and soybean meal with human-inedible by-products in a high-quality forage diet to dairy cows increased net food protein production substantially without lowering milk production.

According to Garg *et al*. (2003) three different iso-nitrogenous concentrate mixtures, were the control consisted of 40% crushed maize grain, concentrate #1 31% de-oiled rice bran (DORB), concentrate #2 26% de-oiled ground nut cake (DGNC) both with 2% mineral mixture and 1% common salt. In concentrate mixtures C1 and C2, maize grain was replaced with de-oiled rice bran DORB at 50 and 100% levels and were fed to three groups of adult ewes. Dry matter intake was similar in groups 53.1, 48.5 and 51.7 g/kgW0.75 for control, C1 and C2 respectively. A similar trend was observed in the digestibility of OM, EE and NDF, which were 63.0, 59.1 and 58.5; 74.9, 76.5 and 73.3; and 55.2, 51.9 and 51.3% in the group fed control diet, C1 and C2 respectively. However, a reduction in Digestibility (%) of ADF was recorded for C1 (45.2%) as compared control (52.7%) and C2 (49.4%).Digestibility of CP was also lower in group fed C3 (48.4%) as compared to groups fed C1 (55.2%) and C3 (53.9%).

Irshaid *et al*. (2003) used sunflower seed meal (SFM) as a substitute for soybean meal (SBOM) in rations of fattening Awassi lambs and milking ewes. The control group ration contained soy bean meal while in the other two rations, sun flower seed meal replaced soy bean meal at a level of 50% and 100% respectively and fourth group was fed only sunflower seed meal. No significant differences were observed between lambs fed the experimental rations in digestibility of DM, OM, CP, CF, NDF, ADF or N balance. The voluntary feed intake was not significant different between rations in voluntary intake. Milk yields (kg/herd per day), milk fat (%) and milk total solids (%) were not different among groups. There were also no significant differences in the average final body weight, average daily gain and average feed conversion ratios among the treatments.

Abubakr *et al*. (2012) assessed the effects of feeding palm oil decanter cake palm kernel cake and palm oil cake on growth, carcass quality and nitrogen metabolism of Kacang ×Boer crossbred male goats in a 100-day experiment. The mixed rations consisted of approximately 16% crude protein on a dry matter basis. Control diet was based on corn grain, soybean meal and rice straw, diet decanter cake diet, palm kernel cake diet and control plus 5% palm oil diet fed to all goats for 21 days before the start of the experiment. Goats fed palm kernel cake diet; had higher feed intake compared to other treatments. Daily gain, slaughter weight, and hot and cold carcass weights were higher in goats receiving control and control plus 5% palm oil diet, than in other goats which were fed decanter cake diet and palm kernel cake diet. It was concluded that a high dietary level of palm oil decanter or palm kernel cake diet (80% of DM) might have an adverse effect on growth performance and carcass quality in goats.

The effect of the partial replacement of the forage in the diet with olive by-products or tomato silages supplemented with sunflower oil (SFO,20 g/kg DM) on rumen fermentation parameters, methane production and milk yield and composition were assessed by Arco-Pérez *et al*. (2017) in lactating Murciano-Granadina goats. Goats were fed control diet (CD) against diets containing olive by-products silage (OBSD) or tomato surplus silage (TSD) in three groups. Both olive by-products silage and tomato surplus silage resulted in higher fat intake and apparent digestibility, higher digestible and metabolizable energy. Diets containing olive by-products silage and tomato surplus silage promoted higher milk fatty acids content. However milk fat of goats consuming tomato surplus silage was lower in C4:0, C6:0 and C8:0 content while olive by-products produced more total saturated fatty acids. The methane production (L/kg DMI) tended to be lower in goats consuming tomato silage supplements. It was concluded that partial replacement of conventional forage by local by-products silage combined with sunflower oil supplementation may be valuable in dairy goats since it may improve the animal energy balance without compromising ruminal fermentation, nutrients utilization and milk yield.

2.15.2.2 Non ruminant animals

Groundnut cake is the major protein supplement utilized in poultry diets in India and many other subtropical countries (Singh and Prasad, 1979). Oil cakes in poultry diets are usually incorporated at levels ranging from10 to 40% (Singh and Prasad, 1979). Sunflower improved the weight of the broiler chicken more than groundnut cake and it appeared that protein in sunflower cake appeared to be better assimilated and utilized for growth than that of groundnut cake (Singh and Prasad, 1979). Inclusion of shea nut cake (a by-product obtained from the processing of shea nut (*Butyrospermum parkii*) to produce shea butter) at increasing levels increased the chemical composition of the diet, the maximum feed intake and weight gain was reported at 25% level of shea nut cake in commercial broiler chicks(AF Boskes strain) (Atuahene *et al*., 1997).

According to Aduku *et al*. (1988), palm oil cake is one of the cheap AIBPs utilized by rabbits which however are fibrous ingredient with about 14.5% crude fibre. The high fibre content has limited the extent to which it can be used in monogastrics diets (Adeniji, 2002). In most cases for the soybean meal or other soybean derivatives which is the standard source of protein, are used in pigs feeding and fat soybean is limited (Stein *et al*., 2016) due to the fact that full fat soybeans contain several components that are undesirable for pigs, most notably trypsin inhibitors. To inactivate the trypsin inhibitors, all soybean products have to be heat treated or toasted prior to use in diets fed to pigs. However, if soybeans are properly heat treated the negative effects of trypsin inhibitors on amino acid digestibility can be reduced (Cervantes-Pahm and Stein, 2008; Baker *et al*., 2010). Yoon and Stein (2013) stated that heat treated full fat soybeans can, therefore, be included in diets fed to all categories of pigs without any negative implications.

Soybean meal is produced from defatted whole or deshelled soybeans (Stein *et al*., 2008). Dehulled soy bean meal contains approximately 48% CP on an as-fed basis, and is sometimes referred to as high-protein soy bean meal. Because of the removal of oligosaccharides, fermented soy bean meal may be included in diets fed to weanling pigs by up to approximately 10% without causing any negative effects (Rojas *et al*., 2015).

Due to the high fiber content of the hulls, sunflower meal is often fed to pigs only if the seeds were partially de-hulled prior to crushing, resulting in a meal that contains approximately 38% CP and 30% neutral detergent fiber (NRC, 2012; Rodriguez *et al*., 2013). However, growing and finishing pigs fed diets containing 10–20% peanut meal as well as 3–4% blood meal had growth performance that was not different from that of pigs fed diets based on SBM (Ilori *et al.,* 1984).

Julio *et al*. (2017) evaluated the energy value of Macadamia nut cake (MNC) for broiler chickens at 4 to 10 days of age. Dietary treatments consisted of a basal diet (no Macadamia nut cake) and a diet containing 60 g/kg of Macadamia nut cake (940 g/kg of basal diet+60 g/kg of Macadamia nut cake). In experiment 2, four dietary treatments were basal control diet (no Macadamia nut cake); 2, 30 g/kg of MNC (970 g/kg of basal diet+30 g/kg of MNC); 3, 60 g/kg of MNC (940 g/kg of basal diet +60 g/kg of MNC); and 4) 90 g/kg of MNC (910 g/kg of basal diet+90 g/kg of MNC) provided from 17 to 23 days of age. The apparent metabolizable energy of MNC was found to be 12.09 and 12.17 MJ/kg in experiment 1 and 2, respectively with an average of 12.13 MJ/kg on DM basis. The results indicate that apparent metabolizable energy of MNC is comparable to conventional feedstuffs with similar nutrient profile, thus can be incorporated in broiler diets.

2.15.3 Performance of livestock fed with horticultural by products feeds

2.15.3.1 Ruminant Animals

Emami *et al.* (2014) investigated the effect of partially replacing cereal grains with pomegranate seed pulp, a by-product of the pomegranate juice industries in a diet. Assessments were made on the performance, nutrient digestibility and antioxidant capacity of fattening Mahabadi goat kids. The goats were fed a control diet which did not contain pomegranate seed pulp, experimental diets containing 5, 10, and 15% of pomegranate seed pulp. Dry matter intake, average daily gain, and feed conversion ratio were not affected by diets. Feed cost per kg of hot and cold carcass weight decreased with increasing levels of pomegranate seed pulp in the diet. Addition of pomegranate seed pulp to diet decreased kidney fat and tended to increase ether extract apparent digestibility. Kids fed 15% of pomegranate seed pulp displayed a greater antioxidant capacity than kids fed control diet.

2.15.3.2 Non-Ruminant Animals

According to Goni *et al.* (2007) inclusion of grape pomace at 30 g/kg and α-tocopheryl acetate (200 mg/kg) in a corn-soybean basal diet of chicken, did not impair chickens growth performance and protein and amino acids digestibility and increased antioxidant activity in diet and excreta. However grape pomace and vitamin E diets reduced the lipid oxidation of meat during refrigerated storage and increased liver α-tocopherol concentration, although these effects were greater, in some cases, by adding vitamin E to the diet performance and protein and amino acids digestibility and increased antioxidant activity in diet and excreta. However grape pomace and vitamin E diets reduced the lipid oxidation of meat during refrigerated storage and increased liver α-tocopherol concentration, although these effects were greater, in some cases, by adding vitamin E to the diet.

In a similar study by Kara *et al*. (2016) , dried grape pomace supplementation at 4% and 6% grape pomace to a corn-soy-based diets did not significantly affect live weight, feed intake, egg production and feed efficiency of 80-week-old Bovans laying . At 4% level grape pomace a significant increase in egg weight was noticed while both 4% and 6% grape pomace supplementation levels significantly increased liver weigh ratio. It was concluded that grape pomace supplementation has the potential to extend shelf life.

CHAPTER THREE

Identification and quantification of the cereal, oil seeds and horticultural agro-industrial by-products in Namibia

3.1 Introduction

Agro-industrial by-products (AIBPs) are defined as residues which are derived from industries due to processing of main products in order to manufacture food products for sale (Sindhu *et al.*, 2002; Jeon *et al.*, 2016). AIBPs can be classified into different categories depending on their origins such as those that originate from fruit and vegetable processing, sugar industry, grain and legume milling, oil industry, distilleries and breweries by-products (Kasapidou *et al.*, 2015; Ajila *et al.*, 2016) or depending on their nutrient composition (Preston 1986; Ajila *et al.*, 2016). Several studies have showed the possibility of exploiting AIBPs as alternative source of feed for livestock (Makkar, 2003; Ben Salem and Smith, 2008), as they play a crucial role by supplying metabolizable energy and crude protein deficient in feed resources during dry period of the year (Atuhaire *et al.*, 2014). Some of the by-products have high nutritive value such as malt distiller's grains with 30.2% CP (Li et al., 2012), 13MJ/kg ME, and an *in vitro* organic matter digestibility in the 65-69% range (Kumae et al., 2015) , and soy bean meal with 47.7 % CP (Itavo et al., 2015), 78.53% *in vitro* organic matter digestibility ,and 9.3 MJ/kg ME (Kumar *et al.*, 2015) are widely used as livestock protein feed sources.

The generation of AIBPs of plant origin is mainly determined by the crops produced in the country and it is directly proportional to the growth of agribusinesses (Azevêdo *et al.*, 2011; Jeon *et al.*, 2016, Sol *et al.*, 2017) and human population growth in the country (Ugwuanyi, 2016). The knowledge of AIBPs quantity generated in any company is critical in defining their importance and use. According to Abdalla *et al*.(2008) AIBPs production is culturally influenced and the quantity generated is influenced by the availability of the raw material, capacity of factory (Sanon, 2007), as well as by the method and processing equipment used (Fadel, 1999). Identification and quantification of AIBPs has a renewed interest due to the need to establish their potential in uses in animal feed production to counteract the feed deficit as well as for other applications such as, fertilizer, functional foods, enzyme and biofuel production, and substrates for edible mushrooms production (Pandey and Soccol, 1998; Mirzaei-Aghsaghali and Maheri – Sis, 2008; Khan *et al*., 2015,) as well as to monitor environmental problems posed by their disposal (Fadel, 1999).

Namibia is a host to some agro-industries that are involved in processing of crops for flour, starch, beer, oil, wines and spirits productions (Trade Policy Framework, 2016). NAMTPS (2011) stated that, cereal grains milling industry is leading and relatively developed among other domestic agricultural processing industries in Namibia. Mushendami *et al*. (2008) indicated that fifty-five percent of cereal grains milling is performed by large scale milling companies while the remaining 45% is shared by small millers in the country (Namibia). In addition Namibia is also host alcohol and beverages producers ranging from well-established large scale industries (Manufacturing and Processing Directory {MPD}, 2015/16) to traditional home based productions (Misihairabgwi and Cheickhyoussef, 2017). Like other African countries where oil extracted from plant seeds are used as source of food, energy medicine and cosmetics (Vermaak *et al*., 2011), cooperatives and projects that are involved in oil extraction from wild plant species such as *Ximenia americana*, *Citrullus lanatus*, *Sclerocarya birrea*, and *Schniziophyton rautaneni* for the production of human edible oil, soups and cosmetics are also found in Namibia (sme.mti.gov.na/ta/mungongo-cooking oil; https://desert- secrets.com/index.php/news/eudafano-women-s-co-operative).

Besides the existence of the agro-processing industries the information on the regard of by-products kinds and quantities, time of availability, and costs, of agro-industrial by-products generated in Namibia is scarce. Due to scarcity of feed ingredient which are normally imported in Namibia, the identification and quantification of agricultural by-products to use as affordable supplements in forages such as bush-based feed and other feedstuff especially during the dry season is vital to increase livestock survival and productivity. Therefore, the aim of this survey was to identify and quantify agro-industrial by-products, as well as to establish their seasonal distribution, uses and costs in Namibia as potential animal feed supplements.

3.2 Materials and Method

3.2.1 Location of the study area

This study targeted the agricultural processing plants of all scales (i.e. small, medium, start –ups, and large scale processing companies) in all the 14 regions of Namibia.

3.2.2 Survey sampling strategy

An online survey was conducted for a period of six months from March to September 2018. The targeted population of the survey was the cereal grains, oil seeds and horticultural products processing companies (at all scales of production) throughout Namibia. Due to a lack of official or reliable documented database of agricultural processors in Namibia, the sample size of the survey could not be pre-determined. The information about the survey was advertised through different communication means such as newspapers, University of Namibia Bush to Feed

Facebook page, and Namibian farmer's association Facebook Page. The survey advert posters (Appendix 1) were also displayed at various places such as Ministry of Agriculture, Water and Forestry (MWAF), Agra, Feed master, Namibian Agronomic Board (NAB), Agro Marketing and Trade Agency (AMTA) and shopping malls in Windhoek in order to attract as many respondents as possible. Phone calls, emails and personal visits were made to agricultural information bodies such as MAWF, AMTA, NAB and Green Scheme Agency in order to obtain referrals to agro-processors in Namibia.

3.2.3 Questionnaire administration

A structured questionnaire (Appendix.2) was designed to provide basic information of respondents, main products produced, seasonal distribution of production schedule and byproduct kind, quantity, management and contamination. The structured questionnaire was available under the link www.surveymonkey.com/r/8L3BK5B. Printed structured questionnaires were also hand delivered to some of the agricultural processors.

3.3 Results

3.3.1 Social-demographic description of the respondents

A total of twenty Namibian agricultural processors successfully responded to the survey (Table 3.1). Sixty-five percent of the respondents were male and thirty-five percent were females. The survey respondents were from seven regions namely: Khomas, Erongo, Oshikoto, Karas, Kavango West, Oshana, and Ohangwena. Khomas region had the highest percentages of responses of 45%, followed by Erongo which had 25% and the rest of the regions had 5% of response each. Majority of the respondents (85%) had tertiary qualifications and minority (15%)

had secondary education (Table 3.1). None of the respondents had primary education as the highest qualification or no education at all.

Table 3.1 Gender and level of education of the survey respondents per regional location

Regions	**Erongo**	**Karas**	**Kavango West**	**Khomas**	**Oshana**	**Ohangwena**	**Oshikoto**	**Total**
Responses (%)	5 (25%)	2 (10%)	1 (5%)	9 (45%)	1 (5%)	1 (5%)	1 (5%)	20 (100)
Female	0 (0%)	1(5%)	0 (0%)	3(15%)	1(5%)	1(5%)	1(5%)	7 (35)
Male	5(25%)	2 (10)	1(4.8)	6 (30)	0 (0)	0 (0)	0 (0)	13 (65)
Level of Education								
Primary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0%)
Secondary	1(5)	0 (0)	0 (0)	2(10)	0(0)	0 (0)	0(0)	3 (15)
Tertiary	4(20)	2 (10)	1(5)	7 (35)	1(5)	1(5)	1(5)	17(85)

Figures in parenthesis ( ) are in percentage.

3.3.2 Agro-industrial by-products identified in Namibia

3.3.2.1 Cereal grain by-products

The cereal by-products identified through the survey are presented in Table 3.2. A total of ten cereal grains by-products were identified namely, sorghum brew residue, pearl millet bran, hominy chop, malt dust coarse, malt dust fine, malted barley, maize chop, wheat bran, traditional spent grains, and industrial spent grains (Appendix.3). Majority (41.66%) of the cereal processing industries indicated that they are operating on a large scale, 25% on a medium, 25% on a small and only 8.3% from startup at a startup scale.

Pearl millet bran was common in four regions namely Kavango west, Khomas, Oshikoto and Ohangwena. Khomas region had a greater diversity of the cereal grains by-products. In addition, responses from all scales of productions indicated that the cereal by-products were available throughout the year. The survey revealed that 66.6% of the cereal by-products are sold in the price range of N$0.20 to 2.90 per kg, 25% are given away to the community for free, and 8.3 % are discarded.

Hominy chop from Oshikoto region had the highest yearly production quantity over 60 0000 kg While Pearl millet bran in Kavango West region had the lowest estimated yearly production of 500 kg. Most of the large scale cereals processing companies could not determine the quantities of the by-products they generate.

Table 3.2 Summary of cereal grains by-products in Namibia identified through the survey.

Cereal by-product	**Region (Resp.)**	**Town**	**Volume**	**Seasonal Availability**	**Production Scale**	**Uses**	**price range**
Sorghum brew residue	Khomas (1)	Windhoek	1000-4000kg/year	Year Round	Medium	Given away For free	Not sold
Pearl millet bran	Khomas (2)	Windhoek	1000 - 4000kg/year	Year Round	Medium	Sold	N$1.50/kg
	Kavango. (1)	Etenderere	500 - 700kg/year	Year Round	Start Up	Given away for fee	Not sold
	Ohangwena (1)	Ondobe	Above 60 000 kg/year	Year Round	Small	Sold	N$2.00/kg
Hominy chop	Oshikoto (1)	Tsumeb	Above 60 000 kg/year	Year Round	Medium	Sold	N$200/ton
Malt dust coarse	Khomas (1)	Windhoek	Not indicated	Year Round	Large	Sold	N$1.90/kg
Malt dust fine	Khomas (1)	Windhoek	Not indicated	Year Round	Large	Sold	N$1.90/kg
Malted barley	Erongo (1)	Swakopmund	Not indicated	Year Round	Small	Given away for free	Not sold
Maize chop	Khomas (1)	Windhoek	Not indicated	Year Round	Large	Sold	N$2.90/kg
Wheat bran	Khomas (1)	Windhoek	Not indicated	Year Round	Large	Sold	N$2.90/kg
Traditional Spent grains	Khomas (1)	Windhoek	800 and 1000kg/year	Year Round	Small	Discarded	Not sold
Industrial spent grains	Khomas (1)	Windhoek	Not indicated	Year Round	Large	Sold	N$2.90/kg

3.3.2.2 Oil seed by-products

Table 3.3 shows the oil seed by-products identified through the survey. The oil seed by-products identified through the survey were marula (*Sclerocarya birrea)* oil seed cake, olive (*Olea europaea*) oil press cake, jojoba (*Simmondsia chinensis*)oil press cake, !nara (*Acanthosicyos horridos*) oil press cake, manketti (*Schinziophyton rautaneni*) press cake. Only Khomas and Erongo regions had responses on oil seed by-products. Marula seed press cake was common for the two regions. The yearly production quantity of most of the oil seed by-products was approximated at 2000kg. Most of the oil seeds by-products are generated from medium scale processing companies and only marula oil press cake from Khomas region is sold.

Table 3.3 Summary of the oil seed by-products identified in Namibia.

Oil seed by-product	**Region (Resp.)**	**Town**	**Production**	**Seasonal availability**	**Scale**	**Use**	**Price**
Marula*(Sclerocarya birrea)* oil press cake	Erongo (1)	Swakopmund	~2000kg/year	Erongo: Jan-April	Medium	Fertilizer	Not sold
	Khomas (2)	Windhoek	~1 800kg/Year	Khomas: Apri-Dec	Medium	Sold	N$2/kg
			~ 100kg/Year	Khomas: April-Dec	Small	Burned	Not sold
Olive (*Olea europaea)* oil press cake	Erongo (1)	Swakopmund	~ 1000kg/year	May-August	Small	Fertilizer	Not sold
Jojoba (*Simmondsia chinensis*) oil press cake	Erongo (1)	Swakopmund	~2000kg/year	Quarterly	Medium	Fertilizer	Not sold
!Nara(*Acanthosicyos horridos*) press cake	Erongo (1)	Swakopmund	~2000kg/year	January-April	Medium	Fertilizer	Not sold
Manketti*(Schinziophyton rautaneni*) press cake	Erongo (1)	Swakopmund	~2000kg/year	January-April	Medium	Fertilizer	Not sold

3.3.2.3 Horticultural by-products

The summary of horticultural by-products identified through the survey is presented in Table 3.4. The horticultural by-products indicated by respondents were potato peels, herb wastes (basil, coriander, lemon sage, thyme etc.), cull vegetables (tomatoes, butter nuts and water melons), and winery and spirits by-products (grape pressings, distilled mash, vine pruning, and lease from wine making). Only those industries which generate potato peels and herbs waste could give the approximate quantity of by-products they produce while the rest could not measure the quantities of their by-products. As shown in Table 3.4 horticultural by-products are given away (potato peels), fed to livestock (Herb waste, tomato, butter nuts and water melon culls), used as a fertilizer (winery and Spirits wastes) and none is sold.

Table 3.4 Summary of the horticultural by-products identified in Namibia

Horticultural by-product	Region (Resp)	Town	Production range	Seasonal availability	Production Scale	By-product use	By-product price
Potato peels	Oshana (1) Khomas (1)	Oshakati Windhoek	110000-30000kg/year	Whole year	small	Given away for free	Not sold
Herb waste	Erongo (2)	Swakopmund	600-1000kg/year	April – December	Small	Fed to livestock	Not sold
Cull vegetables	Karas (1)	Noordower	Not indicated	May-August	Small	Fed to livestock	Not sold
Winery and spirits waste	Erongo (1)	Omaruru	Not indicated	January-August	Medium	Fertilizer	Not sold

3.4 Discussion

The survey received responses from seven administration regions namely: Khomas, Erongo, Oshikoto, Karas, Kavango West, Oshana, and Ohangwena and no response was received from other regions such as Kunene, Omusati, Kavango East, Zambezi, Hardap and Otjozondjupa. Besides cultivation of vegetable crops along rivers in regions such Zambezi and Kavango East as reported by Mushendami *et al*. (2008) and some irrigation scheme productions taking place in regions like Omusati, no responses were received from these regions. This could possibly be attributed to limited accessibility to internet and Agricultural centers where the survey information was accessible or no significant processing is happening in those regions, that year. Namibian Agriculture marketing and Trade policy and Strategy [NAMTPS] (2011) stated that Namibia lack skills and infrastructures for agricultural produce processing which lead to exportation of fresh produces (such as potatoes) to countries like South Africa. Other reasons for lack of responses from these regions could also be ascribed to language barriers as the survey was conveyed in English (official language) and no translation into local languages was done.

Azevêdo *et al*. (2011), Jeon *et al*. (2016) and Sol *et al*. (2017) stated that the generation of AIBPs of plant origin is determined by the crops produced and therefore directly proportional to the growth of agribusinesses and human population growth in the country (Ugwuanyi, 2016). In this study majority (ten) of the identified agro-industrial by-products were cereal by-products compared to six oil seeds by-products and only four horticultural by-products. The high abundance of cereal by-products than other by-products may suggest relatively higher existence of cereal processing activities in Namibia. This is also supported by NAMTPS (2011) stating that cereal grains processing, particularly milling industry is leading and relatively developed among other domestic agricultural produce processing in Namibia.

A similar study done by Bistanji *et al*. (2000) to identify and quantify the potential by-products generated by the agro-industrial sector covering thirty factories in Lebanon revealed a total of fifteen agro-industries having byproducts with potential use for livestock feed. The study by Bistanji e*t al*. (2000) also revealed that commonly used by-products used for feed such as sugar beet pulp, and to some extent molasses and olive oil cake are being sold while similar by-products were either given away for free (potato peels), or used as a fertilizer (olive oil cake) similar to this study

Khomas region had the highest number of cereal by-products. According to Bester (1999) Khomas region (Figure 2.) has also areas encroached by *Acacia mellifera* at a density of 2000 bushes per ha. Therefore, cereal by-products produced in Khomas region (Windhoek) such as sorghum brew residue, malt dust fine, malt dust coarse , malt dust fine ,wheat bran, brewery spent grains and traditional brewing by-products identified in this survey could be good supplements for the bush feed formulations in these areas. Cereal by-products such as hominy chop produced in Tsumeb (Oshikoto region) at a greater volume of 60 000 kg/year could be a good source supplement to *Clossphospermum mopan*e, and *Dichrostachays cinerea* bush feed.

Most of the oil seeds by-products are produced in factories located in Windhoek (Khomas region) and Swakopmund (Erongo). The location of these factories in urban areas could make it difficult to be accessed by poor resources farmers residing in rural areas of Namibia. Sanon (2007) and Alaniamy *et al*. (2017) stated that limited use of agro-industrial by-products in animal feeding relates to location of agricultural processing factories in urban and peri- urban areas which make it expensive for transport the by-products to rural areas where farming is taking place.

Most of the oil seed by-products identified in this study are used as fertilizer. The use of most of the oil seeds as fertilizer in Erongo region could be due to the lack of awareness of the feeding values of these by-products. Some of the by-products such as traditional brewing spent grains which is produced at a volume of 800 kg per year but discarded in landfills could be used along with other ingredients to formulate rations especially during drought which could sustain livestock during dry seasons. Selling of these by-products have also an advantage as it might help to recover processing costs associated with their productions (Thieme *et al*., 2017) and minimize environmental pollutions caused by their disposals.

According to Sanon (2007), the quantity of by-products generated from a factory relates to the availability and capacity of the factory. In Lebanon approximately 140 000 ton of Wheat bran was produced yearly (Bistanji *et al*., 2000) and sold at U$100/ton which is equivalent to N$1.406/ kg. The Namibian wheat bran volume could not be specified and it is sold at a slightly higher price of N$2.90/kg. Bistanji *et al*. (2000) also revealed that 2.40 tons of olive oil cake is produced per season from an individual processing in Lebanon which is relatively higher than 1000 Kg of olive oil cake produced per season by a processing plant in Namibia. Additionally, Olive oil cake is sold at a price of US$10/ton in Lebanon which is equivalent to N$140.62/ton in Namibia where it is used as fertilizer.

Besides cereal, oil seed, and horticultural by-products based mainly in cereal milling, beer making and wines and spirits production, the study of Bistanji *et al.* (2000) also discovered by-products from other companies producing fresh fruit juices and sweets and canning industry. Namibia is also a host to other small processing activates such as wines from local fruits like eembe (*Berchemia discolor*) (Barrion *et al*., 2000). However, these production are small and mostly at the experimental stage. All the cereal by-products are available throughout the year mainly from maize and pearl millet milling which are the leading crops in Namibia (Mushendami *et al*., 2008). Oil seeds and horticultural by-products are produced seasonally mainly during the months of April to December possibly due to their seasonal production and small harvests.

3.5 Conclusion

The results showed that a total of ten cereal by-products, six oil seeds by-products, and four horticultural by-products were identified. Majority of the cereal by-products are available year round and sold at a price in the range of N$1.50 to 2.0/kg. Hominy chop had the highest yearly production above 60 000kg/year. Oil seeds are only available in some of seasons, highest yearly production was 2000kg/year, and majorities are currently used as fertilizer. The horticultural by-products are available only in some of the months and used as fertilizer, given away for free, fed to livestock and none is sold. Potato peels had the highest production volume among all the horticultural by-products. Majority of the horticultural by-products are utilized in animal feeds.

CHAPTER 4

The chemical composition of the agro-industrial by-products identified in Namibia

4.1 Introduction

In Namibia, livestock production is a major contributor to the agricultural sector whilst ruminant wild ungulates play a significant role in the tourism sector. Livestock contribute at least 75% to total agricultural output in Namibia, with beef production being the most important activity, followed by sheep and goats production (Sweat and Burke, 2000). Namibia is an extensive livestock producing country. Due to this, the nutrient content and availability of the natural pastures fluctuate from year to year and between the wet and the dry seasons. An opportunity for alternative feed is provided by agricultural by-products that are produced in the country (Bistanji *et al*., 2000).

Agro-industrial by-products (AIBPs) that are generated in large quantities every year in Namibia would be an excellent choice in conventional diets of livestock due to their availability, their low cost and their nutrient content (protein, energy, minerals and vitamins) (Katsoulis *et al*., 2016). Names of agro-industrial by-products may fail to provide an accurate description and composition of the by-product, this makes their chemical composition analysis essential (Kasapidou *et al.,* 2015). Chemical composition analysis of AIBPs is important to determine the suitability of each in a variety of settings and also make characterization of individual AIBPs possible (Mirzaei-Aghsaghali and Maheri-Sis 2008 & Negesse *et al*., 2009). The chemical compositions of agro–industrial by-products can be studied using laboratory based analyses which primarily measure each individual component of a feedstuff. The initial procedures used to estimate the quantity of an individual component of a feed stuff are the procedures of the proximate analysis.

Agro-industrial by-products differ in chemical compositions due to differences in crop varieties, proportions of botanical fractions, growing conditions (geographic, seasonal variations, climatic conditions and soil characteristics), level of contaminations (foreign materials and impurities such as soil and method used in processing and type of components extracted (Freira *et al.*, 2000; Wenk, 2001; Galassi *et al.*, 2004; Amaefule *et al.*, 2009). These factors all have influences in the precision of feed formulation. Due to lack of data particularly with regards to AIBPs produced in Namibia, the objective of this study was to determine the chemical composition of the AIBPs identified in Namibia.

4.2 Materials and Method

4.2.1 Sample collection and preparation

The samples were collected based on the information from processors that were identified in the first experiment (in Chapter 3). At least 3 kg of each cereal, oil seeds and horticultural by-products was collected from agricultural processing company and then transported to Neudamm campus for further processing. Agro-industrial by-products samples were dried in forced-air drying oven set at 55^0 C for 48 hours and then ground using a hammer mill to pass through 1 mm sieve. About 500 g of ground sample of each agro-industrial by-product was transferred into air tight containers pending chemical analysis.

4.3 Chemical analysis

Chemical composition analysis of the samples was performed at the Ministry of Agriculture, Water and Forestry nutrition laboratory in Windhoek. The dry matter (DM) and organic matter (OM) were determined according to the standard methods of AOAC (1991). The DM was determined by drying sample in forced-air oven at 105ºC over night. Ash content was determined by igniting the samples in a muffle furnace at 550ºC for the duration of 6 hours. OM was determined as DM minus ash. Ether extract (EE) was analyzed according to AOAC (1990) by Soxhlet methods using petroleum ether as dissolving reagent. Nitrogen (N) content was determined by the standard Kjeldhal method (AOAC, 1991) and the amount of crude protein was calculated by Nitrogen content multiplied by 6.25. Oil seed by-products were defatted with acetone prior to fibre analysis. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) was determined according to Van Soest *et al*. (1991). Hemicellulose content was determined as a difference ADF and NDF. Calcium and phosphorus was analyzed by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) (icap 6000 series).

4.4 Statistical analysis

The chemical composition data were analyzed using one way-analysis of variance under a completely randomized design (CRD) using the Statistical Package for the Social Sciences (SPSS) Version 20.0.0. The differences in chemical composition means within cereal grains, and oil seeds by-products were established by Duncan's new multiple range tests (Steel and Torrie, 1980). All the statistical tests were performed at $\alpha = 0.05$ level of significance and variations within were considered significant at $p \leq 0.05$.

4.5 Results

4.5.1 Chemical composition of cereal by-products

The results of chemical composition for the cereal grains processing by-products presented in Table 4.1. The results indicated that brewer's spent grains and sorghum brew residue had the highest ($p \leq 0.05$) DM content of 97.55±0.02 and 97.71 ±0.03, respectively, while Sorghum Spent grains had the lowest DM content of 86.75±0.02%. The ash content was significantly higher ($p \leq 0.05$) in Malt dust coarse (5.39±0.02%) and lowest in White maize chop (2.27±0.01%) and sorghum brew residue (2.26±0.04%**)**.

The brewers spent grains had also the highest ($p \leq 0.05$) CP value of 21.95±0.05% while Sorghum spent grains had the lowest CP content of 7.9±0.00%. There was no significant difference ($p > 0.05$) observed between malt dust fine (15.55 ±0.05%) and wheat bran (15.45±0.005%) as well as between pearl millet bran (12.55±0.05%) and white maize chop (9.30±0.10%) in terms of CP content.

Table 4.1 Chemical composition (%DM) means± standard error terms (SE) of cereal by-products

Cereal By-Product	**DM**	**Ash**	**OM**	**CP**	**EE**	**NDF**	**ADF**	**Hem**	**Ca**	**P**
Malt dust fine	95.50^{c} ±0.43	4.82^{b} ±0.02	90.68^{c} ±0.41	15.55^{d} ±0.05	1.37^{h} ±0.06	39.87^{b} ±0.01	12.21^{c} ± 0.05	27.66^{b} ±0.05	0.15^{b} ±0.01	0.35^{c} ±0.01
Pearl millet bran	93.19^{d} ±0.01	3.23^{d} ±0.01	89.96^{d} ±0.01	12.55^{e} ±0.05	9.29^{a} ±0.06	32.04^{d} ±0.18	7.22^{e} ± 0.00	24.82^{c} ±0.18	0.03^{c} ±0.00	0.62^{b} ±0.00
Malt dust coarse	96.27^{b} ±0.06	5.39^{a} ±0.02	90.89^{c} ±0.08	18.75^{b} ±0.05	1.66^{g} ±0.01	34.46^{c} ±0.33	10.16^{d} ± 0.30	24.30^{c} ±0.04	0.09^{bc} ±0.00	0.62^{b} ±0.01
White maize chop	92.67^{de} ±0.08	2.27^{e} ±0.01	90.40^{cd} ±0.07	9.30^{e} ±0.10	7.53^{c} ±0.02	23.62^{e} ±0.50	7.82^{e} ±0.19	15.80^{e} ±0.31	0.07^{c} ±0.06	0.55^{b} ±0.08
Wheat bran	92.38^{e} ±0.30	4.31^{c} ±0.42	88.07^{e} ±0.12	15.45^{d} ±0.05	4.06^{e} ±0.03	38.59^{b} ±0.56	14.47^{b} ±0.20	24.12^{c} ±0.37	0.08^{c} ±0.01	0.97^{a} ±0.03
Brewer's spent grains	97.55^{a} ±0.02	3.63^{d} ±0.06	93.92^{b} ±0.04	21.95^{a} ±0.25	7.95^{b} ±0.05	73.06^{a} ±0.43	30.46^{a} ±0.58	42.60^{a} ±0.15	0.21^{a} ±0.00	0.50^{b} ±0.01
Sorghum brew residue	97.71^{a} ±0.03	2.26^{e} ±0.04	95.46^{a} ±0.07	17.35^{c} ±0.25	5.70^{d} ±0.07	32.65^{d} ±0.07	15.08^{b} ±0.19	17.57^{d} ±0.12	0.05^{c} ±0.00	0.28^{d} ±0.01
Sorghum Spent grains	86.75^{f} ±0.02	1.34^{f} ±0.01	85.41^{f} ±0.03	7.9^{f} ±0.00	3.32^{f} ±0.12	22.23^{e} ±0.62	9.91^{d} ±0.18	12.32^{f} ±0.44	0.05^{c} ±0.00	0.15^{e} ±0.00

Legend: Moist=moisture, DM=dry matter, EE=ether extract, OM=organic matter, Ca=Calcium, P=Phosphorus, CP **=**Crude Protein, CF=Crude Fiber, ADF=acid detergent fiber, NDF=Neutral detergent Fiber, Hem=Hemicellulose. $^{(a, b, c)}$ Means±SE with different superscripts within a column differ significantly **(**$p \leq 0.05$**).**

The Ether extract (EE) content varied significantly (p≤<0.05) among the cereal by-products. Pearl millet bran had the highest (p≤<0.05) ether extract content of 9.29±0.06% and malt dust fine had the lowest ether extract content of 1.37±0.06%.

The Brewer's spent grains had the highest NDF content of 73.06±0.43% while white maize chop (23.63±0.05%) and sorghum spent grains (22.23±0.62%) had the lowest NDF content. However, there was no significant differences (p>0.05) in NDF content between pearl millet bran (32.04±0.18% NDF) and sorghum brew residue (32.65±0.07% NDF) as well as between Malt dust fine (39.87±0.01%) and Wheat bran (38.59±0.56%).

The brewers spent grains contained the highest (p≤0.05) ADF content of 30.46±0.58% while sorghum spent grains contained the least ADF content of 12.32±0.44%. There was no significant differences (p>0.05) in ADF contents observed between pearl millet bran (7.22±00%) and white maize chop (7.53±0.002%), between malt dust coarse (10.16±0.30%) and sorghum spent grains (9.91±0.18%) as well as between wheat bran (14.47±0.56%) and sorghum brew residue (15.08±0.19%). Brewers spent grains had the highest (p≤0.05) hemicellulose content of 42.60±0.15% and sorghum spent grains (12.32±0.44%) had the lowest. Pearl millet bran (24.82±0.05%), malt dust coarse (24.30±0.30%), and wheat bran (24.12±0.37%) had similar (p>0.05) hemicellulose contents.

Brewers spent grains contained the highest (p≤0.05) Ca (calcium) content of 0.21±0.00% while wheat bran (0.08±0.01) and sorghum brew residue (0.05±0.00% had the lowest and similar (p>0.05) calcium Contents. Wheat bran (0.97±0.03%) had the highest (p≤0.05) phosphorus (P) content while sorghum brew residue (0.28±0.01%) had the least Phosphorus (P) content

4.5.2 Chemical composition of oil seed by-products

The results of chemical composition for the oil seed by-products are presented in Table 4.2. Marula oil cake had the highest ($p \leq 0.05$) DM (dry matter) content of 98.05±0.02% while olive oil cake (95.02±0.02%) and jojoba oil cake (95.15±0.02) had similar ($p > 0.05$) and lowest DM content. The ash content was highest in olive oil cake (5.31±0.00%) and lowest in jojoba oil cake (2.75±0.03 %). Ash contents for marula oil press (5.31±0.00%) and marula oil cake (4.54±0.15) were not significantly different ($p > 0.05$).

Crude protein (CP) content was highest in marula oil press (37.30±0.20%), and lowest in olive oil cake (7.55±0.05%). It was observed in this study that jojoba oil cake (23.90±0.30%) and manketti oil cake (23.95±0.05) had similar ($p > 0.05$) CP content. Marula oil cake had the highest EE (ether extract) content of 53.59±0.08% while !nara oil cake and Manketti oil cake had the least EE content of 8.16±0.10% and 8.11±0.08 %, respectively. Neutral detergent fiber (NDF) was highest ($p \leq 0.05$) in manketti oil cake (58.26±0.35%) but lowest ($p \leq 0.05$) in marula oil cake (11.40±1.21%).Acid detergent fiber was highest ($p \leq 0.05$) in manketti oil cake (52.26±0.57%) and lowest but similar in marula oil press (8.21±1.21%) and marula oil cake (9.57±0.17%). Marula oil press contained the highest ($p \leq 0.05$) hemicellulose content of 29.10±1.44% while marula oil cake (1.83±0.11%) had the lowest hemicellulose content. Calcium content was similar ($p > 0.05$) for all the oil seed by-products analyzed in this study and it was in a range of 0.26 ±0.22 (in manketti oil cake) to 0.09±0.01 %DM (!nara oil cake). Phosphorus (P) was highest ($p \leq 0.05$) in marula oil press (1.09±0.55%) and lowest but similar ($p > 0.05$) in !nara oil cake (0.71±0.03%) and marula oil cake (0.80±0.25%).!Nara oil cake (0.71±0.03%) and marula oil cake (0.80±0.25%) had similar ($p > 0.05$) phosphorus contents.

Table 4.2 Chemical composition (%DM) means± standard error (SE) terms of oil seed by-products

Oil seeds by-products	DM	Ash	OM	CP	EE	NDF	ADF	Hem	Ca	P
Olive oil cake	95.02 ^{c} ±0.02	5.31 ^{a} ±0.00	89.72 ^{d} ±0.08	7.55 ^{d} ±0.05	13.40 ^{c} ±0.14	46.51 ^{c} ±0.51	37.07 ^{c} ±0.97	9.44 ^{b} ±0.46	0.15 ^{a} ±0.00	0.18 ^{c} ±0.00
Marula oil press	95.87 ^{b} ±0.03	4.66 ^{c} ±0.05	91.21 ^{c} ±0.07	37.30 ^{a} ±0.20	48.84 ^{b} ±0.24	37.31 ^{d} ±0.24	8.21 ^{e} ±1.21	29.10 ^{a} ±1.44	0.15 ^{a} ±0.00	1.09 ^{a} ±0.05
Jojoba oil cake	95.15 ^{c} ±0.02	2.75 ^{d} ±0.03	92.40 ^{b} ±0.01	23.90 ^{c} ±0.30	12.97 ^{c} ±0.02	35.16 ^{e} ±0.08	24.29 ^{d} ±0.18	10.87 ^{b} ±0.10	0.10 ^{a} ±0.00	0.37 ^{b} ±0.01
!Nara oil cake	92.90 ^{d} ±0.01	4.87 ^{b} ±0.14	88.08 ^{e} ±0.14	26.15 ^{b} ±0.05	8.16 ^{d} ±0.10	49.46 ^{b} ±0.21	44.83 ^{b} ±0.15	4.63 ^{c} ±0.36	0.09 ^{a} ±0.01	0.71 ^{ab} ±0.03
Manketti oil cake	92.88 ^{d} ±0.10	5.02 ^{ab} ±0.08	87.86 ^{e} ±0.18	23.95 ^{c} ±0.15	8.11 ^{d} ±0.09	58.26 ^{a} ±0.35	52.26 ^{a} ±0.57	6.00 ^{c} ±0.92	0.26 ^{a} ±0.22	0.45 ^{b} ±0.30
Marula oil cake	98.05 ^{a} ±0.02	4.54 ^{c} ±0.15	93.51 ^{a} ±0.14	32.30 ^{b} ±0.05	53.59 ^{a} ±0.08	11.40 ^{f} ±0.06	9.57 ^{e} ±0.17	1.83 ^{d} ±0.11	0.14 ^{a} ± 0.00	0.80 ^{ab} ±0.25

Legend**:** Moist=moisture, DM=dry matter, EE=ether extract, OM=organic matter, Ca=Calcium, P=Phosphorus, CP **=**Crude Protein, CF=Crude Fiber, ADF=acid detergent fiber, NDF=Neutral detergent Fiber, Hem=Hemicellulose. $^{(a, b, c)}$ Means±SE with different superscripts within a column differ significantly **(**$p \leq 0.05$**).**

4.5.3 Chemical composition of horticultural by-products

The chemical composition analysis results of horticultural by-products are presented in Table 4.3. Potato peels only, was studied in this study as a horticultural by-product. Potato peels had a DM content of 89.80±0.02%, 2.45±0.01% of ash and 12.78±0.06% CP.

Table 4.3 Chemical composition (%DM) of potato peels (horticultural by-product).

Potato peels	
Chemical component	Mean ± SE % DM
Dry matter	89.80±0.02
Ash	2.45±0.01
Organic Matter	87.33±0.02
Crude protein	12.78±0.06
Ether extract	2.06±0.07
Neutral detergent fiber	37.31±0.24
Acid detergent fiber	12.53±0.12
Hemicellulose	24.78±0.9
Calcium	0.01±00
Phosphorus	0.30±0.05

4. 6 DISCUSSION

4.6.1 Chemical composition of cereal by-products

4.6.1.1 Dry matter composition of cereal by-products

The dry matter contents of the feed stuff give an indication about their nutrient concentration, because nutrients in feeds are part of the feed dry matter portion. The findings on DM contents of some of the cereal milling by-products (also in literature) in this study were inconsistent with the findings in literature. Such as 93.19±0.01% for pearl millet bran which was lower than 95.30% recorded by Abdou *et al*. (2011), 92.38±0.08% in white maize chop which was slightly higher than 90.2% reported by Ondiek *et a*l. (1997) in Kenya and maize hominy (89.9 %) in Tanzania reported by Asimwe *et al.* (2014), and 92.38±0.08 % in white maize chop which was slightly higher than 90.2% reported by Ondiek *et a*l. (1997) in Kenya and 89.9 % in Tanzania by Asimwe *et al.* (2014). The differences in DM content of these cereal milling by-products could be explained by the possible differences in type (i.e. dry or wet milling) and extent of milling employed (Amaefule *et al.*, 2009) as well as climate, growing conditions, harvesting of the grains (Wenk, 2001), and methods of determination used Getachew *et al*. (2004). Besides that, some findings on DM of some cereal milling by-products were consistent with findings in literature such as 92.38±0.30 % for Wheat bran which was similar to 91.0 % recorded by Habib *et al*. (2012).

For the brewery by-products, the 97.71±0.03 % DM result for brewer's spent grains was higher than the findings of Guermah and Maertens (2016), 86.75 ±0.02 % DM in sorghum spent grains was higher than that of sorghum dry distiller grains (89.0%) recorded by Welker *et al*. (2012). In comparison with some brewery based cereal by-products traditionally used as animal feed supplements such as wheat distiller's grains (92.8% DM) reported by Li *et al*. (2012), malt dust fine (96.27±0.06 % DM), and malt dust coarse (95.50±0.45% DM) and in sorghum brew residue (97.71±71 %DM) had relatively high DM contents. Variations in these cereal brewing by-products could be explained by possibility of variations in the nutrient composition of the parent grains (Penner and Christensen, 2000), drying method, amount of soluble added, fractionation of particle size and heat intensity used in brewing (Schroeder, 2012). However, some of the DM contents for some brewing residues such as 95.50±0.45% DM in Malt dust fine were comparable to similar brewing by-product in literature such as 95.2% DM in Maize dry distiller's grains reported by Li *et al.* (2012).

4.6.1.2 Ash composition of the cereal by-products

The 4.31±0.42% ash content for wheat bran was comparable to 3.9% reported by Habib *et al*. (2012). However, 2.27 ±0.01% ash for white maize chop lower than 4.1 and 3.2% ash reported by Asimwe *et al.* (2014) and Ondiek *et a*l. (1997), respectively, and 2.23±0.01% Ash for pearl millet bran higher than 1.4 % ash reported by Abdou *et al*. (2011).Variation in this ash contents results in this study compared to literature could be explained by possible variations in crop varieties, growing conditions (geographic, seasonal, climatic and soil characteristics), type and extent of milling, levels of contamination, and differences in ash content determination apparatuses.

4.6.1.3 Crude protein composition of cereal by-products

The crude protein (CP) contents range of cereal by-products in this study (9 ±0.00 (in sorghum spent grains to 21.95±0.29 % DM in brewers spent grains) was above 6.0-8.0% CP which is minimum protein requirement for rumen microorganism's activity (Van Soest, 1994 NRC, 2001). Crude protein content of the cereal grains above the recommended protein content for maintenance requirements suggest their potential for ruminant's supplementation for low protein feeds which forms the major particularly during the dry season in Namibia. Protein contents for some of the cereal by-products investigated in this study such as malt dust fine, pearl millet bran, malt dust coarse, wheat bran, brewer's spent grains and sorghum brew residue were above 10 and 15% CP in DM basis, recommended for ruminant fattening and high milk production (Ayisi *et al*., 2002) In this study, the CP content of all the cereal by-products except for sorghum spent grains (Table 4.2) was in excess of the recommended minimum requirements for lactation (120 g/kg DM) and growth (113 g/kg DM) in ruminants (NRC, 2001).

In comparison with literature, 12.55±0.05% CP pearl millet bran in this study was lower than 22.0 % CP recorded by (Abdou *et al*., 2011), 15.45 ±0.05 % CP for wheat bran slightly higher than 14.10% recorded by Gendley *et al*. (2008) while 9.30 ±0.10% CP in White Maize chop lower than 11. 4 and 14.6 % CP recorded for maize chop hominy by Asimwe *et al.* (2014) in Tanzania, and Moate *et al*. (2011) in Australia, respectively. However, 9.30 ±0.10% CP in white maize chop was consistent with 9.5% CP reported by Ondiek *et a*l. (1997) in Kenya while 15.45±0.05 % CP for wheat bran was consistent with 14.1% reported by Gendley *et al*. (2008) and 21.95 ±0.25% CP for Brewer's spent grains was comparable to 22.96 % CP reported by Guermah and Maertens (2016). Differences in CP content of cereal milling by-product in this study could be attributed to possible variations in crop varieties, growing conditions (geographic, seasonal, climatic and soil characteristic), type and extent of milling.

For cereal brewery by-products, higher CP content Sorghum brew residue (17.35±0.25%) than average CP content of for sorghum grains (11.30) stated by Lindsay (2010), was in line with the expectation of Spiehs and Varel, (2009) as well as Salim *et al*.(2013) who stated that brewing cereal grains lead to more concentration of nutrients than in the original grains . According to Klopfenstein *et al*. (2008) and Wood *et al*. (2011) fermentation of the grains makes the by-product (spent grains) to become approximately three times more concentrated in nutrients such as protein, fat, fiber, phosphorus and sulfur than the original grain. However, 7.9±0.00 CP % in Sorghum spent grains lower than the average CP content for sorghum grains (11.30 % CP) was beyond expectation. Lower CP content in sorghum spent grains than expected could be explained by the possible variations of length and method of brewing employed.

4.6.1.4 Ether Extract composition of the cereal by-products

According to McDonald, (2010) Ether extract (EE) also known as crude fat supplies about 2.25 times more energy than carbohydrate. The recommended ether extract range for ruminant animal's diet is any EE% content less than 8%DM (Salah *et al*., 2014). In this study EE content of cereal by-products ranged from 3.32±% EE (in Sorghum Spent grains) to 9.29 ±0.06 %EE (in pearl millet bran). The 4.06 ±0.03 % EE for wheat bran in this study was similar to 3.81% EE reported by Gendley *et al*. (2008). However, the 7.53±0.02 % EE content for white maize chop was lower than 12.2% EE reported in hominy chop (similar by-product to maize chop) reported by Asimwe *et al.* (2014), and 10.0% EE for maize bran reported by Welker *et al*.(2012).The differences in %EE of the cereal milling by-products in this study from that in literature could relate to differences in types of milling methods used which yields by-products of different grains proportions (Amaefule *et al.*, 2009), differences in crop varieties, and EE determination apparatus and methods used (Getachew *et al*., 2004).

For the cereal brewery by-products, 7.95±0.05% EE for brewer's spent grains was lower than 10.34 % EE reported by Guermah and Maertens (2016) while 3.32±0.12 % EE for the sorghum spent grains was very lower than 9.8% EE for sorghum dry distiller's grains reported by Welker *et al*., (2012). Different EE contents for cereal brewing by-products investigated in this study compared to literature could be ascribed to possible variations in the nutrient composition of the parent grain (Penner and Christensen, 2000), drying method, amount of soluble added, fractionation of particle size and heat intensity used in brewing (Schroeder, 2012).

Except from pearl millet bran which had 9.29% EE content slightly higher than 8% EE, all the other cereal by-products had % EE content less than 8% recommended for maintenance of ruminant livestock animals diets (Salah, 2014). Low concentrations of EE in cereal grains by-product in this study suggest their valuable source of energy supplements to fibrous feeds such as bush feed especially when an oil seed by-product is to be included into ruminant rations. According to Molina –Alcaide *et al.* (2003) a diet containing more than 32.1 % EE DM can limit intake and may reduce fiber digestion in the rumen (Alqaisi and Hemme, 2014).

4.6.1.5 Neutral detergent fiber (NDF), acid detergent fiber (ADF), and hemicellulose contents of the cereal by-products

Fiber in the diet of ruminant animals is important for maintenance of optimal rumen functions by forming a rumen mat (Kung, 2014). The fiber from the rumen mat is regurgitated and chewed producing large amounts of saliva that buffers the rumen (Kung, 2014) Fiber fractions have effects on the dry matter intake and chewing activities of the particular feed. Sau (2013) stated that high NDF in feed ingredients decreases dry matter intake. In addition, for legumes NDF content below 40% is considered good quality while above 50% is considered poor. For grass NDF below 50% would be considered high quality and above 60% as low quality while ADF below 35% in legume or grass would indicate good quality. For the diets, Kolver (2003) stated that for a good quality ruminant diet, NDF percentage should range between 35 and 70 % DM, while ADF should be below 31 % DM (Geleti *et al*., 2013). In this study In this study the NDF values of the cereal grains by-products ranged from 22.23 ±0.62% NDF (in sorghum spent grains) to 73.06±0.43 % (in brewer's spent grains), while ADF values were in the range of 15.08± 0.19 ADF (in sorghum brew residue) to 30.46 ±0.58% ADF (brewer's spent grains) .Low NDF and ADF for the majority of cereal by-products in this study below 40% NDF and 35% ADF content suggest their potential in supplementing fibrous ruminants diets such as bush based feed.

White maize chop had 23.62 ±0.50 % NDF and 7.82 ±0.19% ADF, lower than 29.9 % NDF and 9.3 % ADF contents reported by Ondiek *et a*l., (1997), while 7.82 ±0.19% ADF in white maize chop similar to 7.5% ADF reported by Asimwe *et al.* (2014) .The 23.62 ±0.50 % NDF of white maize chop was similar to 22.7% NDF reported by Moate *et al*. (2011) in Australia. For wheat bran the 38.59±0.56% NDF content was lower than 45.01% NDF reported by Gendley *et al*.(2008) and 14.47±0.20% ADF content was similar to 14.28 % Gendley *et al*. (2008) ADF value. Brewer's spent grain 73.06±0.43 NDF, and 30.46±0.58% ADF were higher than 49.14% NDF and but lower than 19.16 % ADF reported by Guermah and Maertens (2016). The 32.02±0.18 % NDF for pearl millet bran is lower than 38.3 % NDF reported by Abdou *et al*. (2011). The differences in the fiber contents of the brewery by-products can relate to possible variations of the grains cultivars used, brewing methods and extent of brewing used as well as protocols of fiber content determination employed (Getachew *et al*., 2004).

4.6.1.6 Calcium and phosphorus contents of the cereal by-products

The calcium content in pearl millet bran (0.03±0.00 % DM) was slightly lower than 0.05%DM reported by Abdou *et al*. (2011) in Niger. The calcium content in wheat bran (0.08±0.01%) was lower than 0.28 % reported by Gendley *et al*. (2008) in India. The differences in calcium contents could relate to variations of cultivar and growing conditions of the grains used. The phosphorus content in cereal grains processing by-products ranged between 0.15 ±0.00 0.97±0.03 % DM. Sorghum distillers grains with soluble reported to contain 0.7 % DM phosphorus by Welker *et al*. (2012) in United States of America which is relatively higher compared to phosphorus content result of sorghum spent grains (0.15±0.00 %) investigated in this study. The Phosphorus content in white maize chop (0.55±0.08 %) is low than maize bran which is a similar by-product reported by Welker *et al*. (2012) in Canada. According to Salah (2014) the recommended calcium and phosphorus maintenance in ruminant diets is 15.4 mg/kg and 16 mg/kg (i.e. 0.0154 g/kg A and 0.016 g/kg) respectively. The lower phosphorus content reported in this study could be attributed to the lack of minerals mainly phosphorus in the Namibian soil (Els *et al*., 1999).

4.6.2 Chemical composition of oil seed by-products

4.6.2.1 Dry matter content concentrations of the oil seed by-products

High percentages of dry matter content in feedstuff may suggest a greater concentration of other nutrients. The 98.05±0.02 % DM content of marula oil cake is comparable to 98.6% DM reported by Ítavo *et al*. (2015) for Soy bean cake which is the standard protein feed source. The dry matter content of jojoba oil cake in this study (95.15± 0.02%) was higher than 91.9 and 93.1 % reported by Nasser (2009) and Verbiscar et *al*. (1980), respectively. While 95.02±0.02 % DM content of olive oil cake (95.02±0.02%) in this study higher than 88.0 and 93.2 % DM reported by Fadel and El-Ghonemy (2015) and Ferrer *et al*. (2017), respectively. The variations in DM contents of jojoba oil cake and olive oil cake investigated in this study compared to that in literature could be attributed to variations in growing conditions, quality of the seeds and oil extraction methods (Dhillon et al., 2016).The difference in dry matter contents between similar by-products (i.e. marula oil cake (98.05±0.00) and marula oil press (95.87±0.03) could be attributed to possible variation in seeds quality and oil extraction methods.

4.6.2.2 Ash content concentrations of the oil seed by-products

The 5.31±0.00 % ash content of olive oil cake ash content lower than 7.0 and 8.3% ash reported by Fadel and El-Ghonemy (2015) and Ferrer *et al*. (2017), respectively could be attributed mostly to the variations in growing conditions of the olives, quality of the olive seeds and ash contents determination methods (Getachew *et al*., 2004 ; Lee *et al*., 2018). Similarly, 2.75 ±0.03% ash for jojoba oil cake lower than lower than 4.1and 3.1% reported by Nasser (2009) and Verbiscar *et al*. (1980), respectively could relate to variations in growing conditions, seeds quality and oil extraction methods. However, in terms of ash (mineral contents) some of the locally available oil seed by-products were comparable to widely used oil seed by-products. For instance, 5.02 ±0.08% ash content for manketti oil cake was comparable to 5.2% ash for soy bean cake reported by Ítavo *et al*. (2015), and 4.61% in Groundnut oil cake reported by Ghosh and Mandal (2015). While 4.54 ±0.15% ash content of marula oil cake and 4.66±0.05% ash of marula oil press was comparable with 3.6% ash for sunflower oil cake reported by Itavo *et al*. (2012) and 4.61% for the groundnut oil cake reported by Gosh and Mandal (2015).

4. 2. 3 Crude protein concentration of the oil seed by-products

The 7.55±0.05% CP of olive oil cake slightly higher than 6.66 % CP DM reported by Ferrer *et al*. (2017) could be explained by possible variations in growing conditions of the olives, quality of seeds as well as extraction methods. A variation in crude protein content in similar oil seed by-products was observed between 37.30±0.20% CP of marula oil press (by-product of marula kernels by cold press extraction method) and 32.30±.0.05 % CP in marula oil cake (by-product of marula oil by an expeller extraction method which employs heat treatments of the oil seeds prior extraction). According to Lee *et al*. (2018) oil seed by-products which are a result of oil extraction method involving cooking and exposing oil seeds to high pressure normally tend to have higher oil and digestible nutrients embedded within the fiber matrix. Apart from variation in methods of oil extraction, the lower CP content in marula oil cake compared to marula oil press could be explained by possible variations in marula kernel quality owing to differences in growing conditions and varieties in marula plants, harvesting as well as handling of the marula fruits. The 23.90 ±0.30 CP in jojoba oil lower than 29.1 % reported by Nasser (2009), could be attributed to possible variations in Jojoba growing conditions, extraction, and CP determination method (Dhillon *et al*., 2016).

Edible oil seed extraction by-products are classified as protein and energy ingredients with high livestock feeding value (Oliveira *et al*., 2007). The crude protein content of oil seeds by-products investigated in this study are above the 6 to 8% CP DM recommended for protein requirements of ruminants for maintenance (Salah, 2017).

4.6.2.4 Ether Extract concentrations of the oil seed by-products

Marula oil press and marula oil cake had EE content of 48.84 ±0.24 and 53.59±0.08 % EE respectively, which were relatively higher than 20.4 % DM EE in canola oil cake reported by Kolesarova *et al*. (2011), i.e. highest ether extract content encountered for oil seeds by-products in literature. The finding of marula oil press EE content of 48.84 ±0.24 % less than 53.59±0.08% for Marula oil cake is in line with the expectation of Lee *et al*. (2018) that oil seeds by-products which have been cooked or exposed to high temperature will be expected to contain more oil and other nutrients embedded within the fiber matrix.

Although oil seeds by-products are typically included in the ration to increase the energy density of the diet while maintaining acceptable fiber levels. Feeding ruminants animals with diets containing more than 32.1% of crude fat can limit the intake and makes it difficult to store it for a long period on the farm. High oil content reduces rumen fermentation by increasing fat and free fatty acids content and its high polyphenol and lignin content inhibits rumen fermentation (Sansoucy *et al*., 1985; Zaidi *et al*., 2008 Álvarez-Rodríguez *et al*., 2009). Ether extract content 13.40 ±0.14% in olive oil cake was higher than 5.7 and 3.4% DM reported by Oliveira1*et al*., (2015) in Egypt and Ferrer *et al*. (2017), respectively, while 12.97 ±0.02 % EE% in jojoba oil cake was higher than 4.1 and 3.1 % DM reported by Nasser (2009) and Verbiscar *et al*. (1980), respectively. Differences in EE% of olive oil cake and jojoba oil cake could as well be explained by possible variations in growing conditions, quality of raw materials (seeds), as well as EE determination methods. On the other hand high residual fat in the oil seed by-products may suggest low efficiency of the oil seed extraction methods employed (Getachew et al., 2004; Dhillon *et al*., 2016; Lee et al., 2018).

4.6.2.5 Neutral detergent fiber (NDF), Acid detergent fiber (ADF) and hemicellulose concentrations of the oil seed by-products.

The NDF content of olive oil cake (46.51 ±0.51%) in the present study was lower than 62 % NDF reported by Ferrer *et al*. (2017), while the ADF content (37.07±0.97) was higher than 22.7 reported by Ferrer *et al*. (2017). The NDF and ADF jojoba oil cake (JJOC) is 35.16±0.08 and 24.29 ±0.18% DM respectively which are lower than 49.7%DM NDF and 25.7 % DM ADF Verbiscar *et al*., (1980). The differences could be explained by possible differences in seeds quality which is mainly determined by growing conditions and harvesting and oil extraction methods.

4.6.2.6 Calcium and phosphorus composition of the oil seed by-products

Jojoba oil cake calcium content investigated in this study 0.10 ±00% DM was lower than 0.9% DM recorded by Verbiscar *et al*. (1980).This could be attributed to differences in the growing conditions, seed quality, harvesting, extraction methods and protocols of calcium content determination. The phosphorus content of oil seed processing by-products was in the range of 1.09±0.05 to 0.18 ±0.00 %. According to Salah *et al*. (2014) the recommended maintenance requirements for calcium and animals diets is 15.4 mg/kg and 16 mg/kg per body weights respectively. The phosphorus content of jojoba oil cake 0.37±0.01% DM was similar to 0.35% DM reported by Verbiscar et *al*. (1980).

4.6.3 Chemical composition of horticultural by-products

The dry matter content of potato peels (89.78±0.02 %) in this study was lower than 98.1% reported by Whittemore (1977), possibly due to variation in potato peeling methods employed, drying, potato varieties and variations in potato crops growth conditions (Bampidis and

Robinson, 2006; Kasapidou *et a*l., 2015). The ash content potato peels (5.57±0.65%) in the present study is similar to 6.22% reported by Ncobela e*t al*. (2017). The crude protein (12.78±0.6%) is similar to 12.30 % reported by Ncobela *et al*., (2017) but higher than 8.25 % reported by Whittemore (1977) while NDF for the potato peels (37.07 ±0.24%) was lower than 41.00% reported by Ncobela *et al*. (2017) and ADF (12.41±0.12%) found in this study for the potato peels is lower higher than 6.30 % reported by Ncobela *et al*. (2017). possibly due to variation in potato peeling methods employed, the potato varieties and variations in potato crops growth conditions**.**

4.7 Conclusion

The chemical compositions differed among cereal and oil seed by-products. The DM content in cereal by-products ranged from 86.75±0.02 to 97.71±0.03% while for the oil seed by-products ranged from 95.02±0.02 % (in olive oil cake) to 98.05±0.02 (marula oil cake).CP in cereal by-products ranged from 7.9±0.00 %(in sorghum spent grains) to 29.95±0.05 (brewer’s spent grains) while for oil seed by-products ranged from 7.55±0.05 (in olive oil cake) to 37.30±0.02 (in marula oil press cake). There were variations in terms of chemical compositions for some of the by-products in from literature which could be explained by differences in crop varieties, proportions of botanical fractions, growing conditions, level of contaminations and different determination approaches.

CHAPTER FIVE

In vitro gas production, organic matter digestibility and metabolizable energy of the cereal, oil seed and horticultural agro-industrial by-products

5.1 Introduction

The ability of the feedstuffs to sustain animal performance depends mainly on its nutritive value. The nutritive value of ruminant feedstuffs is determined by the concentrations of its chemical compositions, as well as rate, and extent of digestion in the rumen (Kumar *et al*., 2015). Different methods are used to ascertain the worth of feedstuffs of ruminant animals. Digestibility evaluations monitor the degradation of cell walls in feeds mainly due to enzymes produce by rumen bacteria, protozoa and fungi (Elghandour *et a*l., 2013). Three major biological digestion techniques are currently available to determine the nutritive value of ruminant feeds: 1) digestion with rumen microorganisms as in Tilley and Terry (1963) or using a gas method (Menke and Steingass1988), 2) *in situ* incubation of samples in nylon bags in the rumen (Mehrez and Orskov, 1977), and 3) cell-free fungal cellulase De Boever *et al.*, 1986).

According to Getachew *et al*. (2004) *in vitro* methods appear to be remarkable for estimating feedstuff digestibility compared to *in situ* methods. Additionally, Carro *et al*. (1994) stated that although in vivo trials seems to be best methods, they appear to be time consuming, laborious, expensive, require large quantities of feed. On a contrary vitro trials are less time consuming, cheaper and more efficient when large number of samples are to be handled (Kumar *et al*. 2015). In particular, *in vitro* gas production technique is used to determine the nutritive values of feedstuffs, since rate and extent of degradation and rumen fermentation can be easily determined by measurement of gas production (Dhanoa *et al*., 2000).

According to Spanghero *et al*. (2018) *in vitro* gas production method entails the incubation of the feed in the buffered rumen, *in vitro* over a period of time to produce gas which as a result of bicarbonate buffer and volatile fatty acids reaction. Gas production is directly related to the rate at which the substrate is degraded (Dhanoa *et al*., 1995). Instead of measuring disappearance of insoluble feed components, as occurs in other *in situ* and *in vitro* methods, the gas production technique measures appearance of gas which is directly generated from fermentation of organic matter (OM) as well as gas released from the buffer in relation to acid products of end-products of fermentation.

The gas produced after 24 hours of *in* vitro incubation together with chemical analysis (EE, CP and ash) of the feed are used to estimate the metabolizable energy (ME) contents of the feeds for ruminants (Tagliapietra *et al*., 2011). The kinetics of gas production depends on the relative proportions of soluble, insoluble but degradable and undergradable particles of the feed (Getachew *et al*., 1998). Feed chemical composition (carbohydrate, protein and fat content) and physical (particles size) characteristics have an influence in the capability of digestive enzymes to colonize and digest the feed particles (Kitessa *et al*., 1999). According to Makkar (2005) stated that there the *in vitro* gas is related to the amount of OM digested. However, the degree of correlation between *in vitro* gas and digested OM is influenced by various factors such as different equipment, differences in protocol, feed ,inoculum characteristics, which all alter release of gas from the medium (Tagliapietra *et al*., 2010). *In vitro* digestibility analysis of the AIBPs can assist in the preliminary evaluation of the nutritive value which would enable identification of the suitable feeds digestible to the livestock ruminant’s animals. The objective of the study was to determine *in vitro* gas production, organic matter digestibility and metabolisable energy (ME) content of agro-industrial by-products identified in Namibia as potential ruminant feed supplements.

5.2 Materials and Method

5.2.1 Location of the experiment

The *In vitro* gas production of agro-industrial by-products experiment was performed at Directorate of Agricultural Research and Development Laboratory, Ministry of Agriculture, Water and Forestry (MAWF), in Windhoek.

5.2.2 Experimental design

A completely randomized design (CRD) with two replications was employed to determine and compare rumen *in vitro* gas production of the cereal grains, oil seeds and horticultural agro-industrial by-products.

5.2.3 *In vitro* gas production analysis

5.2.3.1 Source of inoculum

Rumen inoculum was obtained from a fistulated Simmentaler steer at Bervleg Veterinary Research Station in Windhoek where it (steer) was fed with Lucerne diet three days prior to rumen inoculum collection. The rumen inoculum was collected in the morning before feeding with a manual pump and transferred into a pre-warmed insulted thermos flask. The rumen inoculum in the thermos flask was flushed with carbon dioxide after collection and then immediately transported to the laboratory where it was filtered with two layers of cheese cloth.

5.2.3.2 *In vitro* incubation procedure and gas measurements

The in *vitro gas* production was carried out according to the *in vitro* gas test procedure of Menke and Steingass (1988). Agro-industrial by-products investigated in this study were cereal by-products (malt dust fine, pearl millet bran, white maize chop, wheat bran, brewers spent grains, sorghum brew residue and sorghum brewers spent gains), oil seed by-products (olive oil cake, marula oil press, jojoba oil cake, !nara oil cake, manketti oil cake and marula oil cake) and horticultural by-products (potato peels). For each by-product, a sample of about 203mg milled to pass through a 1mm sieve was weighed and placed into calibrated glass syringes in duplicates. One part of rumen fluid was added to two parts of buffer mineral solution (1:2, volume / volume). This buffered rumen fluid was then pippeted into incubation syringes containing the substrate. No headspace was left in the syringes and all handlings were performed under continuous flushing with CO_2 to maintain anaerobic conditions. Three syringes were included as blanks. Hay and concentrate feed samples each in three syringes was used as standards. The syringes were then incubated an incubator containing the rotating disc maintained at 39°C. Gas production was read and recorded after the first 8 hours of incubation by opening the clip to let the air out and moving the piston back at 30ml position. The incubation of syringes was terminated after 24 after incubation had commenced were the final reading of *in vitro* gas production was done.

5.3 Calculations

Gas production at 24 hours from a standard hay meal (GPH) and a concentrate (GPC) standard were used as correction factor.

The correction factor for hay meal (FH) is:

$FH = 44.6 / (GPC – GP_0) = 0.86$

While that of concentrate mixture (FC) is:

$FC = 62.6 / (GPC – GP_0) = 0.85$

The total gas values were corrected for the blank incubations

$$GP\ (ml/200\ mg\ DM) = \frac{(XV1 – 30\ X + V\ final - V0 – GP_{blank}) \times 200\ ((FH + FC)/2)}{Weight\ in\ mg\ DM}$$

Where: X = the number of times that the gas is released from the syringe and the volume is set back to 30 m, V0 = the initial volume of gas recorded before incubation start, V1 = the volume of gas recorded before the gas is released from the syringe and the volume is set back to 30 ml, Vfinal = the final volume of gas recorded at the end of incubation time, and GP0 = the mean blank value

And concentrate hay mixture: Corrected GP= GP×CF

The *in vitro* gas production at 24 hours corrected to concentrate mixture was used to calculate the organic matter digestibility (OMD) and metabolizable (ME) according to the equations of Close and Menke, (1986); and Menke and Steingass, (1988):

OMD (%) =14.88+0.889GP (ml/200 mg DM) +0.45CP+0.0651 Ash (%DM)

ME (MJ kg $^{-1}$ DM) =1.06+0.157 GP (ml/200 mg DM) +0.084CP (%DM) - 0.081ash (%DM)

Where: OMD =organic matter digestibility; ME = metabolizable energy; GP =24 h net gas production (ml/200 mg DM); CP = crude protein (% DM) CF = crude fibre (%DM). EE = Ether extract (% DM).

5.4 Statistical Analysis

The *in vitro* gas production, organic matter digestibility and metabolizable energy data for cereal and oil seed by-products data were analyzed using one way-analysis of variance under a completely randomized design (CRD) using the Statistical Package for the Social Sciences (SPSS) Version 20.0.0. The statistical differences *in vitro* gas, OMD and ME means within cereal grains, and oil seeds by-products were established by Duncan's New Multiple Range Tests (DMRT) (Steel and Torrie, 1980). All the statistical tests were performed at $\alpha = 0.05$ level of significance and variations within were considered significant at $p \leq 0.05$. While for horticultural by-products only descriptive were computed for means since only one by-product was analyzed in this category.

5.5 Results

The result of the *in vitro* gas production (GP), organic matter digestibility (OMD) and metabolizable energy (ME) for the cereal grains by-products after 24 hours of incubation are presented in Table 5.1. White maize chop had the highest ($p \leq 0.05$) net *in vitro* gas production of 70.20 ±1.30 ml/200mg DM while brewer’s spent grains had the lowest ($p \leq 0.05$) net *in vitro* gas production of 31.50±2.40 ml/200mg DM. Wheat bran and sorghum brew residue had similar ($p > 0.00$) in vitro gas volumes of 56.30±0.50 ml/200mg DM and 54.10±3.50ml/200mgDM, respectively. White maize chop had the highest ($p \leq 0.05$) OMD of 83.5±0.30% DM and highest (p≤0.05) ME of 14.00±0.00 MJ/kg DM. Brewer's spent grains with the lowest (p≤0.05) OMD of 55.55±0.50 % DM had the lowest ME of 9.30±0.00 MJ/kg DM.

Table 5.1 *In vitro* gas production (GP), Organic Matter Digestibility (OMD) and metabolisable energy (ME) of cereal by-products after 24 hours of incubation in the rumen fluid.

Cereal grains by-products	**Mean Corrected GP at 24 hrs (ml/200mg DM)**	**Organic Matter Digestibility (%)**	**Metabolizable Energy (MJ/kg DM)**
Malt dust fine	52.55±0.33[d]	72.95±0.25[b]	10.50±0.00[g]
Pearl millet bran	60.10±2.40[bc]	76.60±0.00[b]	13.20±0.00[b]
Malt dust coarse	57.30±0.50[bcd]	79.60±1.40[b]	11.40±0.00[f]
White maize chop	70.20±1.30[a]	83.5±0.30[a]	14.00±0.00[a]
Wheat bran	56.30±0.50[cd]	75.50±0.10[b]	11.60±0.00[e]
Brewer's spent grains	31.50±2.40[e]	55.55±0.50[c]	9.30±0.00[h]
Sorghum brew residue	54.10±3.50[cd]	72.45±0.15[b]	11.70±0.00[d]
Sorghum brew spent grains	63.05±1.65[b]	76.00±00[b]	11.95±0.00[c]

[a,b,c,d]Means±SE with different superscripts within a column differ significantly (p ≤ 0.05).

The *in vitro* gas production (GP), organic matter digestibility (OMD) and metabolizable energy (ME) of the oil seed by-products after 24 hours incubation in the rumen fluid are presented in Table 5.2. Jojoba oil cake's had the highest *in vitro gas* production volume after 24 hours of 35.30 ±0.90 ml/200 mg DM while marula oil press had the lowest *in vitro* gas production of 3.80±0.40 ml/200mg DM. Jojoba (*Simmondsia chinensis*) oil cake had the highest (p≤0.05) OMD of 59.35±0.15 % DM while marula (*Sclerocarya birrea*) oil press had the lowest (p≤0.05) OMD of 38.95±0.15 %DM. Olive *(Olea europaea)* oil cake and !nara (*Pterocarpus indicus*) oil cake had similar ($p>0.05$) OMD of 46.25 ±0.05%DM and 46.65±0.15 %DM respectively. Marula oil press had the highest ($p\leq0.05$) metabolizable energy of 15.95±0.05 while marula *(Sclerocarya birrea)* oil cake had the lowest ME of 7.45 MJ/kg.

Table 5.2 *In vitro* gas productions (GP), Organic Matter Digestibility (OMD) and metabolisable energy (ME) of oil seed by-products after 24 hours of incubation in the buffered rumen fluid

Oil seeds by-products	**Mean Corrected GP at 24 hrs (ml/200mgDM)**	**Organic Matter Digestibility (%)**	**Metabolizable Energy (MJ/kg)**
Olive oil cake	27.15 ± 0.05^{b}	46.25 ± 0.05^{c}	8.90 ± 0.00^{c}
Marula oil press	3.80 ± 0.40^{e}	38.95 ± 0.15^{e}	15.95 ± 0.05^{a}
Jojoba oil cake	35.30 ± 0.90^{a}	59.35 ± 0.15^{a}	11.20 ± 0.00^{b}
!Nara oil cake	19.65 ± 0.55^{cd}	46.65 ± 0.15^{c}	7.75 ± 0.05^{d}
Manketti oil cake	16.85 ± 0.05^{d}	44.10 ± 0.20^{d}	7.75 ± 0.05^{e}
Marula oil cake	19.50 ± 0.40^{c}	50.10 ± 0.10^{b}	7.45 ± 0.05^{e}

$^{a, b, c}$ Means±SE with different superscripts within a column differ significantly ($p \leq 0.05$).

The *in vitro* gas production (GP), organic matter digestibility (OMD) and metabolizable energy (ME) of horticultural by-product investigated in this study after 24 hours incubation in the rumen fluid are presented in table 5.3.

Table 5.3 *In vitro* gas production (GP), Organic Matter Digestibility (OMD) and metabolisable energy (ME) of horticultural by-product after 24 hours of incubation in the buffered rumen fluid.

Horticultural by-products	Mean corrected GP at 24 hrs (ml/200mg)	Organic Matter Digestibility (%)	Metabolizable Energy (MJ/kg)
Potato Peels	60.40±1.70	79.60±0.10	11.05±0.05

5.6 Discussion

5.6.1 *In vitro* gas production, organic matter digestibility and metabolizable energy of cereal grains by-products.

According to Guerma and Maertens (2016) the determination of agro-industrial by-products nutritive value is a fundamental step towards their inclusion in animal feed formulations. *In vitro* gas production technique measures appearances of gas which is directly produced from fermented OM as well as gas released from the buffer in relation to acid properties of the end products of fermentation in the rumen. The *in vitro* gas produced is directly proportional to the extent at which the substrate is degraded. High rates of in vitro gas production are influenced by soluble carbohydrate fractions readily available to ruminal microbes (Deadville and Givens, 2001).

In this study white maize chop had the highest in vitro gas production of 70.20±1.30 ml/200 mg among the cereal by-products investigated. High *in vitro* gas production from white maize chop indicates that it consisted of highly fermentable carbohydrates which increased gas production by the rumen microbes. White maize chop also had the highest OMD of 83.50±0.30% DM and highest metabolizable energy of 14.00±0.00 MJ/kg DM. Additionally the findings on white maize chop was in agreement with Makkar (2005), who stated that a positive relationship exist between the gas produced *in vitro* and OMD digestibility. However it was also noted in this study that the metabolizable energy of white maize chop (14.00MJ/kg DM) was lower than that of a similar maize milling by-products hominy chop which has 16.6 MJ/kg DM of ME (Moate *et al*., 2010). The differences in ME could be attributed to possible differences in chemical composition of the maize grains, varieties of maize, methods and extent of milling, differences of metabolizable energy determination protocol and inoculum properties.

Wheat bran had an OMD of 75.50±0.10 % DM which is higher than 68.5 % DM and GP of 56.30 ml higher than 48.99ml/200mg DM reported by Kumar *et al*. (2005). However, ME value of wheat bran (11.60 MJ/kg) in this study was similar to 11.50% reported by Hamid *et al*. (2007). The variations in *in vitro* gas production and OMD discovered in this study to that one of Moate *et al*. 2010 could be ascribed to possible differences in cultivars of wheat, chemical compositions, growing and harvesting conditions, extent of milling, GP and OMD determination protocol as well as inoculum characteristics.

Brewer's spent grains in this study was less digestible (55.55% OMD) than that investigated by Habib *et al*. (2011) which had 60.28% OMD. Brewer's spent grains also contained lower metabolizable energy (9.30±0.00 MJ/kg) than 15.70 MJ/kg reported by Moate *et al*. (2011). According to Menke and Steingass (1988), *in vitro* gas production from the medium is influenced by chemical composition which also influences the extent at which the feed constituents are fermented. High NDF content of 73.06 ±0.43% of Brewer's spent grains could have contributed to its lower GP production and OM digestibility. According to Al-Masri (2003) and Getachew *et al*. (2004) NDF content of the feed has a negative impact on *in vitro* gas production, OM digestibility and ME. Getachew *et al*. (2000) and Tagliapietra *et al*. (2011)

stated that the dietary CP content of feed was found to strongly reduce the amount of gas released *in vitro*.

Brewer's spent grains had the highest CP content of 21.95±0.25% DM amongst the other cereal by-products. In particular, Cone and Van Gelder (1999) stated that low *in vitro* gas production in protein rich feeds, can relate to the fact that protein fermentation produces NH_3, which has an inhibitory effect on the release of indirect gas. Therefore high CP content in Brewer's spent grains might have contributed to its low *in vitro* gas production and OM digestibility.

Some of the local cereal by-products such as sorghum brew residue and sorghum spent grains had good *in vitro* gas production potential and were highly digestible. Sorghum brew residue had an *in vitro* gas production of 54.10±0.50 ml/200mg DM and 72.45±0.15% OM digestibility while Sorghum brew spent grains had 63.05±1.65 ml/200mg DM and 76.00% OM digestibility. Their ruminal metabolizable energy were also high and this indicates that they consist of low contents of less structural carbohydrate content which could supply substantial amount of energy for rumen microbial growth.

5.6.2 *In vitro* gas production, organic matter digestibility and metabolizable energy of oil seed by-products

In this study oil seeds by-products had a lower *in vitro* gas production after 24 hour of buffered rumen fluid incubation compared to the cereal grains and horticultural by-products. Lower *in vitro* gas production could have been inhabited by their high fat contents which was in the range of 8.11 -53.59 % DM. Although fat is a good source of energy value of as it provides 2.25-fold more energy than carbohydrates or proteins and constitute the primary attraction for their use in feed (Morais *et al.*, 2015). Aderbal *et al*. (2015) warned that when fat levels exceed 5 to 7% of the diet, or when the diet is rich in unsaturated fatty acids, digestive disorders involving reduced lowered feed intake may occur. In addition, high fat levels in the rumen also interfere with the digestive process by coating the contents of the rumen, particularly when digesting fiber.

Jojoba oil cake had the highest *in vitro* gas production of 35.30±0.40 ml/200mg DM and highest OM digestibility of 59.35±0.15% DM amongst the other oil seed by-products. Highest GP and OM digestibility of Jojoba oil cake could relate to lower levels of NDF content. Jojoba oil cake had the second lowest NDF content of 35.16±0.08 % DM amongst the oil seed by-products. Jojoba oil cake also had the second highest ME content of 11.20±0.00 MJ/kg DM. This suggests that jojoba oil cake have a potential of rumen fermentation and therefore could potentially supply energy for metabolism.

Marula oil press had the lowest in vitro gas of 3.80±0.04ml/200mg DM and low OM digestibility of 38.95±0.15%DM compared to 19.50±0.40 ml/200mg DM and OM digestibility of 50.10±0.10 % of marula oil cake. Besides high *in vitro* gas production and OM digestibility of marula oil cake, marula oil press had the highest metabolizable energy (ME) of 15.95±0.05 MJ/kg compared to 7.45±0.05 MJ/kg in Marula oil cake. The differences could be related to differences in chemical compositions of these two similar by-products. In particular, marula oil cake had a higher CP content (37.30^{a}±0.20 % DM) and lower EE content of 48.84±0.24 % DM compared to 32.30±0.05 % DM CP and 53.59±0.08 % DM EE of marula oil cake. Differences in *in vitro* GP and OM digestibility between marula oil cake and marula oil press could also be attributed to differences in extraction methods that were employed for oil extraction.

The metabolizable energy (ME) of marula oil press (15.95±0.05) was higher than 13.4MJ/kg DM of soybean meal (standard protein source) reported by Hamid *et al*. (2007).The metabolizable energy of marula oil cake (7.45±0.05 MJ/kg DM) and manketti oil cake (7.75±0.05 MJ/kg) were comparable to 6.9 MJ/kg ME reported by Sheresias *et al*. (2015) and 7.1 MJ/kg DM ME of cotton seed cake reported by Kumar *et al*. (2018). The OM digestibility of Olive oil cake (46.25±0.05 %) was higher than 41.8% reported by Ayadi *et al*. (2013).

In comparison to cereal and horticultural by-products, oil seed by-products had lower GP volumes. Tagliapietra *et al*. (2011), the dietary CP content of feeds was found to strongly reduce the amount of gas released. Cone and Van Gelder (1999) stated that low *in vitro* gas production in protein rich feeds, can relate to the fact that protein fermentation produces NH_3, which has an inhibitory effect on the release of indirect gas. The assumption that gas production is linearly related to the rate and the extent of feed digestion is questionable, as GP is strongly affected by feed chemical composition (Makkar, 2005). The organic matter digestibility of olive oil cake findings of 46.8% is higher than 41.8% DM reported by Ayadi *et al*. (2013). Lower *in vitro* GP from the oil seed by-products could also be attributed to the possibility of the presence of phenolic compounds, such as lignin, which increase the indigestible fraction of the feed and reduce the potentially digestible fraction (Mizubuti *et al*., 2011)

5.6.3 *In vitro* gas production, organic matter digestibility and metabolizable energy of horticultural by-products

Potato peels had *in vitro* gas volume of 60.40±1.70 ml/200mg DM after 24 h of incubation in the buffered rumen fluid. This was very higher than 25.5 ml/200 mg DM reported by Negese *et al*.(2016) DM. The Metabolizable energy value of potato peels (11.0 MJ/kg DM) in this study were a half more than 5.01 MJ/kg DM reported by Negese *et al*. (2016). Variations in *in vitro* gas production and ME findings of this study from that of Negese et al. (2016) could be attributed to possibility of variations in the chemical compositions of the potato peels, and processing methods (Getachew *et al*., 2004).

CHAPTER SIX

CONCLUSIONS AND RECOMMENATIONS

6.1 General discussion and conclusions

The study identified ten cereal by-products namely: sorghum brew residue, pearl millet bran, hominy chop, malt dust coarse and malt dust fine, malted barley, maize chop, wheat bran, traditional sorghum spent grains, and industrial spent grains. According to the respondents all the cereal by-products can be available throughout the year. Pearl millet bran was common for many regions. The studies revealed that majority (66.6%) of the cereal by-products identified are currently sold while 25% are given away to the community and 8.3% are discarded. The sold cereal by-products included pearl millet bran, hominy chop, malt dust coarse and fine, maize chop, wheat bran, and Industrial spent grains. The price range of the sold cereal by-products was N$0.20 to N$2.90/kg. Cereal by-products given away for free included sorghum brew residue, pearl millet bran in some regions, malted barley, and traditional spent grains from (from tombo brewing) was discarded. The study indicated that hominy chop and pearl millet bran had the highest yearly production volumes over 60 000 kg while pearl millet bran from Kavango west had the lowest yearly production volume of 500 kg.

The study also identified oil seed by-products namely marula oil seed cake, olive oil seed cake, jojoba oil cake, !nara oil cake, and manketti oil cake mainly from Khomas and Erongo region. All the oil seed by-products are available only in some seasons particularly from the stretch of April to December. Among all the oil seed by-products identified, only marula oil seed cake is sold. Majority of the oil seeds by-products are used as fertilizer and minority is burned as a mean of their disposal. Horticultural by-products identified included potato peels, herb wastes, cull vegetables (tomatoes, butter nuts, and water melons), winery and spirits by-products (grape pressings, distilled mash, vine prunings, and lease from lease from wine making). Horticultural by-products are only available some of the seasons and their yearly production volumes could not be determined.

The chemical composition differed significantly among the cereal, oil seeds and horticultural by-products categories. All the agro-industrial by-products investigated in this study were above the recommended CP content (6.0-8.0% DM) required for rumen microbial activities. Brewer's spent grains with the highest CP content (21.95±0.29), its yearly production volume could not be determined but available year round. Sorghum spent grains which had the lowest CP content of 9.00 % had a yearly production volume of 1000-4000kg. This volume could be substantial since sorghum spent grains is a brewery by-product which can only be included at a low level in ruminants feeds due to their high sulfur contents (Spiehs and Varel 2009). According to Wadhwa and Bakshi (2016). in ruminants diets brewer's grains are included at 30-40% growing beef cattle, up to 40% finishing beef cattle, 30% lactating dry cows, up to 20% growing and finishing lamb and 25% lactating ewes.

Some of the high fermentable by-products such as white maize chop and pearl millet bran had high OM digestibility as well as high metabolizable energy. These qualities could make them suitable potential energy and protein supplement for fibrous feeds in Namibia such as bush based feed. Marula oil press had the highest CP content of 37.30±0.20 % and highest metabolizable energy of 15.95±0.5 MJ/K demonstrating a strong potential for use as protein and energy supplement to the bush feed which is characterized by high fiber and low protein content. Potato peels also had good protein content of 12.78±0.06 %DM along with 79.60±0.10 OM digestibility and 11.05 MJ/kg which could be as well present a good quality for protein end energy supplement for the bush feeds and other fibrous feeds.

6.2 Recommendations

This study indicated that numerous by-products demonstrated a greater potential for use as supplements in ruminant's livestock feeds. If these agro-industrial by-products could be fully exploited as supplement to innovative feeds such as bus-based feed, the livestock productivity and drought survival rates in Namibia especially during the dry seasons could be increased. Although some of the oil seed by-products identified were rich in protein, their high fat content could present a challenge in storage and might as well interfere with rumen fiber digestibility. That may suggest a need for further research to be done to further characterize the agro-industrial by-products in terms of palatability, feed intake, in vivo digestibility, animal response trials and anti-nutritional factors which could enable to determine the optimal inclusion levels for different classes of ruminant animals. There is also a need to assess the seasonal effects on nutrient quality of the agro-industrial by-products more research is needed to identify and characterize more by-products that this study could not identify.

REFERENCES

Abdou, N., I. V. Nsahlai, and, M. Chimonyo. 2011. Effects of groundnut haulms supplementation on pearl millet stover intake, digestibility and growth performance of lambs. J. Anim. Sci. 169: 176-184.doi:10.1016/j.anifeedsci.2011.07.002

Abubakar, A. R., A. R. Alimon, H. Yaakub, N. Abdullah, and, M. Ivan. 2013. Growth, nitrogen metabolism and carcass composition of goats fed palm oil by-products. Small Ruminant Research. 112: 91-96. http://dx.doi.org/10.1016/j.smallrumres.2012.11.003.

Adeniji, A. A., and, O. A. Omonijo. 2004. The replacement value of palm kernel cake for groundnut cake in the diets of weaner rabbits, Livestock Production Science 85: 287–291.https://doi.org/10.1016/S0301-6226 (02)00196-3

Ajila, C. M., S. K. Brar, M. Verma, R. D. Tyagi, S. Godbout, and, J. R. Valéro, J. R. 2012. Bio-processing of agro-byproducts to animal feed. Critical Reviews in Biotechnology, 32(4): 382–400. https://doi.org/10.3109/07388551.2012.659172

Akhtar, T. 1983. Effect of low doses of gamma radiation on nutritive value of guar (*Cyamopsis tetragonaloba*) meal, used in broiler rations. M.Sc. Thesis, University of Agriculture, Faisalabad, Pakistan.

Al-Masri, M. R. 2003. An *in vitro* evaluation of some unconventional ruminant feeds in terms of the organic matter digestibility, energy and microbial biomass. Trop. Anim. Health and Prod. 35 (2): 155-167.

Almeida, F. N., G. I. Petersen, and, H. H. Stein. 2011. Digestibility of amino acids in corn, corn coproducts, and bakery meal fed to growing pigs. J. Anim. Sci. 89:4109–4115.

Alnaimy, A., A. E. Gad, M. M. Mustafa, M. A. A. Alta, and, H. A. M. Basouny. 2017. Using of citrus by-products in animal feeding. Open Acces J Sc 1(3):00014.doi:10.15406/oajs.2017.01.0014

Alqaisi,O. T. Hemme, U. Latacz-Lohmann, and, E. Susenbeth .2014. Evaluation of food industry by-products as feed in semi-arid dairy farming systems : the case of Jordan, 2007, 361–377. https://doi.org/10.1007/s11625-013-0240-6

Álvarez-Rodríguez, J. F., Muñoz and, J. Margalida. 2009. Nutritive value of crude and extracted two-stage olive cakes produced in Aragón (Spain). Revista electrónica de Veterinaria, 10 (3).

Alves, S. V., A.M. Silva, L. R. Bezerra, H. Carneiro, F. F.Medeiros, J. M. P Filho, M.N. Moreira and R. L. Oliveira. 2015. *In vitro* fermentation and gas production of oilseed press cake.Chilean J.Agric.Anim.Sci.ex Agro-Ciencia 31 (1): 43-51.

Amaefule, K. U., S. F. Abasiekong, S. N. Ibe and, O. C. Onwudike. 2009. Digestibility and nutrient utilization of some agroindustrial by-products fed to growing pigs in the humid tropics.Pakistan Journal of Nutrition 8: 355–360.

Angassa, A.. and, G. Oba. 2008. Effects of management and time on mechanisms of bush encroachment in southern Ethiopia. African Journal of Ecology. 46: 186–196.

Annual Trade Statistics Bulletin .2016. Available at https://cms.my.na/assets/documents/Annual_Trade_Statistics_Bulletin_2016.pdf.

Arco-Pérez, A., E. Ramos-Morales, D. Yáñez-Ruiz, L. Abecia, and A. Martín-García. 2017. Nutritive evaluation and milk quality of including of tomato or olive by-products silages with sunflower oil in the diet of dairy goats. Animal Feed Science and Technology 232:57-70. http://dx.doi.org/10.1016/j.anifeedsci.2017.08.008.

Asimwe, L., A. E. Kimambo, G. H. Laswai, L. A. Mtenga, M. R. Weisberg, J. Madsen, and D.E Mushi. 2015. Growth performance and carcass characteristics of Tanzania Shorthorn Zebu cattle finished on molasses or maize grain with rice or maize by-products. Livestock Science 182: 112-117.http://dx.doi.org/10.1016/j.livsci.2015.11.001.

Atuahene, C. C., A. Donkoh, and F. Asante. 1998. Value of sheanut cake as a dietary ingredient for broiler chickens. Animal Feed Science Technology 72:133–142.

Atuhaire, A.M., S. Mugerwa, S. Okello, K. Lapenga, F. Kabi, G. Lukwago. 2014. Prioritization of Agro-industrial By-products for Improved Productivity on Smallholder Dairy Farms in the Lake Victoria Crescent, Uganda. Frontiers in Science 4, 1-7.

Avezedo, J. A. G., S. C. Filho, D. S. Pina, E. Detmann, L. G. R. Pereira, R. F. D. Valadares, H. J. Fernandes, L. F. Costa e Silva, and P. D. Benedeti. 2012. Nutritional diversity of agricultural and agrp-industrial by-products for ruminant feeding. Arg. Bras. Vet. Zootec. 46: 1246-1255.

Ayadi, M., A., Arakrak, M, and M. Chentout. 2013. Chemical composition, *in vitro* digestibility and fermentation kinetics of arboricultural and agro industrial by-products in the North of MorDCC in: Ben Salem.H. (ed), Lopez-Francos (ed.). Feeding and management strategies to improve livestock productivity, welfare and product quality under climate change. CIHAEM,FAO:2013.127-132.

Ayisi, K. K., H. K. Mokoboki, and L. R. Ndlovu. 2002. Chemical and physical parameters of forage legume species introduced in the Capricorn region of Limpopo Province: South African Journal of Animal Science, *32*(4).

Baker, K. M., and, H. H. Stein. 2009. Amino acid digestibility and concentration of digestible and metabolizable energy in soybean meal produced from conventional, high-protein, or low-oligosaccharide varieties of soybeans and fed to growing pigs. J. Anim. Sci. 87: 2282–2290.

Ball, D. M., M. Collins, G. D. Lacefield, N. P. Martin , D. A. Mertens, , K. E. Olson, , D. H. Putnam, r, D. J. Undersander and, M. W. Wolf. 2001. Understanding forage quality. American Farm Bureau Federation Publication 1–01, Park Ridge, IL.

Bampidis, V. A., and, P. H. Robinson. 2006. Citrus by products as ruminant feeds: A review. Animal Feed Science and Technology, 128, 175–217

Barekatain M. R., C. Antipatis, M. Choct, and, P. A. Ajil. 2013. Interaction between protease and xylanase in broiler chicken diets containing sorghum distiller's dried grains with solubles. J. Anim. Sci. 182:71-81. http://dx.doi.org/10.1016/j.anifeedsci.2013.04.002.

Ben Salem, H. M. 2004. Toward better utilization of non-conventional feed sources by sheep and goats in some African and Asian countries. In: Ben Salem H. (ed.), Nefzaoui A. (ed.), Morand-Fehr P. (ed). Nutrition and feeding strategies of sheep and goats under harsh climates .pp. 177-187. Zaragoza: CIHEAM.

Bistanji, G., S. Hamadeh, H. Hassan, F. Tami and R. Tannos. 2000. The potential of agro-industrial by-products as feeds for livestock in Lebanon. Livestock Research for Rural

Development (12) 3 2000. Available at: http://www.fao.org/livestock/agap/frg/lrrd/lrrd12/3/bist123.htm. Accessed 11 January 2019.

Böttger , C., and, K. H. Südekum. 2017. European distillers dried grains with soluble (DDGS): Chemical composition and in vitro evaluation of feeding value for ruminants. Animal Feed Science and Technology 224 , 66–77. https://doi.org/10.1016/j.anifeedsci.2016.12.012.

Boucqué, C. H. V., and L. O. Fiems. 1988. Vegetable by-products of agro-industrial origin. Journal of Livestock Production Science. 19: 97–135.

Brewer, L. R., J. Kubola, S. Siriamornpun, T. J. Herald, and Y. C. Shi. 2014. Wheat bran particle size influence on phytochemical extractability and antioxidant properties. Food Chemistry.152: 483–490.

Carro, M. D., S. Lopez, J. S.Gonzalez and F. J. Ovejero. 1994. Comparison of laboratory methods

Church, D. C., and, W. G. Pond. 1979. Basic animal nutrition and feeding. 3rd ed. John Wiley and Sons. Prentice Hall International Inc, UK.

Coda, R., K. Katina, and, C. G. Rizzello. 2015. Bran bioprocessing for enhanced functional properties. Curr. Opin. Food Sci. 1:50–55

Colombo, A., P. D. Ribotta, and, A. E. León. 2010. Differential scanning calorimetry (DSC) studies on the thermal properties of peanut proteins. Journal of Agricultural and Food Chemistry.58: 4434–4439.

Cozannet, P., Y. Primot, C. Gady, J. P. Métayer, M. Lessire, F. Skiba and J. Noblet. 2010. Energy value of wheat distillers grains with solubles for growing pigs and adult sows. Journal of Animal Science. 88: 2382–2392

Crawshaw, R. 2004. Co-product feeds: animal feeds from the food and drinks industries. Nothingham University Press.

Das, N. G., K. S. Huque, S. M. Amanullah, and, H. P. S. Makkar. 2018. Feeding of processed vegetable wastes to bulls and its potential environmental benefit. Animal Nutrition. 4–11. https://doi.org/10.1016/j.aninu.2018.04.002

De Boever, J. L., B. G. Cottyn, F. X. Buysse, F. W. Wainman, and J. M. Vanacker. 1986. The use of an enzymatic technique to predict digestibility, metabolizable and net energy of compound feedstuffs for ruminants. Anim.Feed Sci. Technol. 14, 203–214.

De Klerk, J. N. 2004. Bush Encroachment in Namibia. Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management Project. Ministry of Environment and Tourism, Windhoek.

De las Fuentes, L., B. Sanders, A. Lorenzo, S. Alber. 2004. AWARENET: Agro-Food Wastes Minimisation and Reduction Network. In Total Food Exploiting Co-Products—MinimizingWaste.-Workshop Report; Total Food Exploiting co-products—Minimizing waste; Proceedings Volume; Waldron, K.W., Faulds, C.B., Smith, A.C., Eds.; Institute of Food Research: Norwich, UK, 2004. pp. 233–244.

de Morias, R. K., A. M. A. Silva, L. R. Bezerra, H. Carneiro, M.N. Moreira and, F.F. Medeiros. 2015. In vitro degradation and total gas production of by-products generated in the biodiesel production chain. Acta Scientarum.37:143-148. Doi.10.4025/actaciaScianimSc.v37i2.26039.

Deaville, E. R., A. R Moss., and D. I. Givens. 1994. The nutritive value and chemical composition of energy-rich by-products for ruminants. Anim. Feed Sci. Technol. 49, 261–276.

Devendra, C. 1993. Sustainable animal production from small farm systems in South –East Asia. FAO conference preceedings, Rome, Italy.

Dhillon, G. S., S. Kaur, H. S. Oberoi, M. R. Speir, and, S. K. Brar. 2016. Chapter 2 - Agricultural-Based Protein By-Products: Characterization and Applications. Protein Byproducts. Elsevier Inc. https://doi.org/10.1016/B978-0-12-802391-4/00002-1

Egbunike, G. N., and, A. E. Ikpi. 1990. Can agro-industrial by-products and crop residues save the Nigerian livestock industry. Department of Animal Science and Agricultural Economics. Universituy of Ibadan. Nigeria.

El Hag, G. A. and, T. B. Miller. 1972. Evaluation of whisky distillery by-products. VI. The reduction in digestibility of malt distiller's grains by fatty acids and the interaction with calcium and other reversal agents. Journal of Food Science and Agriculture. 23 (2): 247–258.

El Mekawy, A., L. Diels, H. De Wever, and D. Pant. 2013. Valorization of cereal based bio refinery byproducts: reality and expectations. Environ. Sci. Technol. 47: 9014–9027.

El-Boushy, A., and, F. B. van der Poel. 2001. Formulating feed from waste and by-products. World Poultry. 17:34–36.

Elghandour, M. M. Y., A. Z. M. Salema, M. Gonzalez-Ronquillo, J. L. Bórquez, H. M. Gado, N.E. Odongo, and C. G. Pe˜nuelasa. 2013. Effects of exogenous enzymes on in vitro gas production kinetics and ruminal fermentation of four fibrous feeds. Animal Feed Science and Technology. 179: 46– 53. http://dx.doi.org/10.1016/j.anifeedsci.2012.11.010.

Eliyahu,D., E. Yosef, Z. G. Weinberg, Y. Hen, M. Nikbachat, R. Solomon, S. J. Mabjeesh and, J. Miron. 2015. Composition, preservation and digestibility by sheep of wetby-products from the food industry. Animal Feed Science and Technology 207:1–9. http://dx.doi.org/10.1016/j.anifeedsci.2015.05.005

Els, J. F., P. T. Jessen and, H. Von Sydeliytz. 1999. Strategies of feeding animals: Strategies of feeding animals in central and Southern Africa. Ed. DH Holness Proc.ZSAP/FAO workshop. Harare15-27 October.pp. 47-52. Retrieved from www.FAO.org/docrep/004/AC152 E/AC 152. html.

Emami, A., M. Ganjkhanlou, M. H. F. Nasri, A. Zali and L. Rashidi. 2015. Pomegranate seed pulp as a novel replacement of dietary cereal grains for kids. Small Ruminant Research. 123: 238-245. http://dx.doi.org/10.1016/j.smalrumres.2014.12.001.

Eshiett, N. O. and, A. A. Ademosun. 1981. Effect of feeding cassava peel meal to growing pullets on their subsequent laying performance. Bull. Anim. Health Prod. Afr.29: 237-242.

Fadel, J. G.1999. Quantitative analyses of selected plant by-product feedstuffs, a global perspective, 79.

FAO. 2008. Livestock, a major threat to environment. Rome, Italy. Available at http://web.archive.org/web/20080328062709/http%3A//www.fao.org/newsroom/en/news/2006/1000448/index.

FAO. 2012. Use of lesser-known plants and plant parts as animal feed resources in tropical regions, by Emmanuel S. Quansah and Harinder P.S. Makkar. Animal Production and Health Working Paper. No. 8. Rome.

FAO. Protein sources for the animal feed industry. Proceedings: Expert Consultation and Workshop Bangkok, Thailand.

Fioli, C., J. D. Hancock, C. Monge, T. L. Gugle, S. D. Carter, and N. A. Cole. 2007. Effects of corn and sorghum-based distillers dried grains with solubles on growth performance and carcass characteristics in finishing pigs. Journal of Animal Science. 85: 95-111

Franke, K., U. Meyer, H. Wagner, H. O. Hoppen, and G. Flachowsky. 2009. Effect of various iodine supple- mentations, rapeseed meal application and two different iodine species on the iodine status and iodine excretion of dairy cows. Livestock Sci. 125 (2–3): 223–231.

Freira, J. P. B., A. J. G. Guerreiro, L. F. Cunha, and, A. Aumaitre. 2000. Effect of dietary fibre source on total tract digestibility, caecum volatile fatty acids and digestive transit time in the weaned piglet. Animal Feed Science and Technology. 87: 71–83.

Galassi, G., G. M. Crovetto, L. Rapetti,and A. Tamburini. 2004. Energy and nitrogen balance in heavy pigs fed different fibre sources. Livestock Production Science 85, 253–262

Garcia, H., L.F. Wang, J. L. Landero, E. Beltranena, M. Cervantes, A. Morales, R. T. Zijlstra. 2015. Effect of feeding wheat millrun on diet nutrient digestibility and growth performance in starter pigs. Anim. Feed Sci. Technol. 207: 283–288.

Garg, A. K., P. Singh, R. Malik, and, D. K. Agrawal. 2004. Effect of replacing maize grain with de-oiled rice bran on intake and utilization of nutrients in adult ewes. Small Ruminant Research. 52: 75-79.

Gasmi-Boubaker, A., C. Kayouli and A. Buldgen, 2005. In vitro gas production and its relationship to in situ disappearance and chemical composition of some Mediterranean browse species. Anim. Feed Sci. Technol., 123-124: 303-311.

Geis, W. 1971. A preliminaryVegitation map of South West Africa. Denteria 4, 5-114.

Gendley, M. K., P. Singh, A. K. Garg, S. P. Tiwari, K. Kumari, and G. K. Dutta. 2009. The studies on nutrient balances in crossbred cattle bulls fed chopped green sugar cane tops supplemented with some agro industrial by-products. Tropical Animal Health Production. 41:941-949.

Getachew, G., P. H. Robinson, E.J. De Peters and S. J. Taylor. 2004. Relationships between chemical composition, dry matter degradation and in vitro gas production of several ruminants feed. Anim. Feed Sci. Technol. 111: 57-71.

Giess, W. 1998. A Preliminary Vegetation Map of Namibia. 3rd Revised Edition. Dinteria .4: 1-112.

Goni, I., A. Bernes, C. Centeno, V. Viveros, F. Saura-Calixto, A. Rebole, I. Arija, and , R. Estevez. 2007. Effect of dietary grape pomace performance and vitamin E on growth nutrient digestibility and susceptibility to meat lipid oxidation in chickens. Poultry Science 86:508-516

Greiner, L., C. Neill, G.L. Allee, X. Wang, J. Connor, K. Touchette, and, J. L. Usry. 2015. The feeding of dried distillers' grains with solubles to lactating sows. J.Anim. Sci. 93:5718–5724.

Guermah, H., and L. Maertens. 2016. Feeding value of brewer's grain and maize silage for rabbits.11th World Rabbit Congress-June 15-18, 2016-Qinqdao-China.

Habib, G., N. A. Khan, M. Ali and, M. Bezabih. 2013. *In situ* ruminal crude protein degradability of by-products from cereal, oil seeds and animal origin. Livestock Science. 153: 81-87.

Hamid, P., T. Akbar, J. Hossein and, M. G. Ali. 2007. Nutrient digestibility and gas production of some tropical feeds used in ruminant diets estimated by *in vivo* and *in vitro* gas production techniques. American Journal of Animal and Veterinary Science 2(4):108-113

Honsbein, D., K. Shiningavamwe, and, J. Iikela. 2017. Animal Feed From Encroacher Bush. Brochure based on a research project jointly implemented by the Ministry of Agriculture, Water and Forestry ,Deustsche Gassellschaft fur International Zusammenarbeit (GIZ) and United Nations Development Programme (UNDP)-Sustainable Management of Namibia Forest Lands Project (NAFOLA).www.dasnamibia.org/download

Ilori, J. O., E. R. Miller, D. E. Ullrey, P. K. Ku, and, M. G. Hogberg. 1984. Combinations of peanut meal and blood meal as substitutes for soybean meal incorn-based, growing-finishing pig diets. J. Anim. Sci. 59: 2-10.

Irshaid, R. H., M. Y. Harb and, H. H. Titi. 2003. Replacing soybean meal with sunflower seed meal in the ration of Awassi ewes and lambs,Journal of Feed science and Technology 50, 109–116. https://doi.org/10.1016/S0921-4488(03)00118-4

Ítavo, L.C.V., C. M. Soares, C. C. B. F. Ítavo, A. M. Dia, H. V, Petit, E. S. Leal, and, A. D. de Souza. 2015. Calorimetry, chemical composition and in vitro digestibility of oil seeds. Food Chemistry. 185: 219-225.

Jeon, S., K. Sohn, and, S. Seo. 2016. Evaluation of feed value of a by-product of pickled radish for ruminants : analyses of nutrient composition, storage stability, and in vitro ruminal fermentation. J. Anim. Sci. 58:34 -49. https://doi.org/10.1186/s40781-016-0117-1

Joubert, D. F., and I. Zimmermann. 2002. The potential impacts of wood harvesting of bush thickening species on biodiversity and ecological processes. Proceedings of the First National Research Workshop held on 12 and 13 March 2002 in Windhoek, Namibia, Ministry of Environment and tourisim, Forestry Publication 9:67-78.

Julio, D. B., S. Yadav, and, R. Jha. 2017. Nitrogen-corrected apparent metabolizable energy value of macadamia nut cake for broiler chickens determined by difference and regression methods. Animal Feed Science and Technology. 234: 65-71. doi:http://dx.doi.org/10.1016/j.anifeedsci.2017.09.009

Kara, K.; B. K. Güçlü, E. Baytok and, M. Şentürk. 2016. Effects of grape pomace supplementation to laying hen diet on performance, egg quality, egg lipid peroxidation and some biochemical parameters, Journal of Applied Animal Research. 44:1, 303-310, DOI: 10.1080/09712119.2015.1031785

Karlsson, J., R. Sporndly, M. Lindberg, and, K. Holtenius. 2017. Replacing human-edible feed ingredients with by-products increases net food production efficiency in dairy cows. J. Diary Sci. 107: 7146-7155. http://doi.org/10.3168/jds.2017-14209.

Kasapidou, E., E. Sossidou., and P. Mitlianga. 2015. Fruit and Vegetable Co-Products as Functional Feed Ingredients in Farm Animal Nutrition for Improved Product Quality. Agriculture, 5(4), 1020–1034. https://doi.org/10.3390/agriculture5041020

Katsoulis, K., L. Leontides, and G. Kontopidis. 2016. Locally Produced Agricultural By-Products as Feed Sources for Pigs. J Veter Sci Med, 4 (1) 5.

Kerdiles, H., F. Rembold, and A. Perez-Hoyos. 2015. Seasonal Monitoring in Namibia. Severe drought affecting cereal production and pastoral areas in Nothern and Cenntral Namibia. European Union.https://mars.jrc.ec.europa.eu/

Kgosikoma ,O., W. Mojeremane, and, B. A. Harvie. 2012b. Bush encroachment in relation to rangeland management systems and environmental conditions in Kalahari ecosystem of Botswana. African Journal of Agricultural Research.7: 2312-2319.

Kgosikoma, O. E., B. A. Harvie, and, W. Wojeremane. 2012a. Bush encroachment in relation to rangeland management system and environmental conditions in Kalahari systems of Botswana. African Journal of Agricultural Research. 7(15):2312-2319.Doi:10.5897/AJAR11.2374

Kindness, H., J. L. N. Sikosana, V. Mlambo and J. F. Morton. 1999. Socio-economic surveys of goat keeping in Matobo and Bubi Districts. Natural Resources Institute Report No. 2451. UK: Chatham Maritime.

Kitessa S, P. C. Flinn, and G. G. Irish. 1999. Comparison of methods used to predict the *in vivo* digestibility of feeds in ruminants. Aust .J. Agric Res.50:825-841.

Klopfenstein, T. J., G. E. Erickson, and, V. R. Bremer. 2008. Board-invitedreview: use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223–1231.

Kolber, H. 1996. Country report to the FAO international technical conference on plant genetic resources. National plant genetic resources center. Windhoek, Namibia.

Kolesarova, N., M. Hutnan, I. Bodýk, and, V. Spalkova. 2011. Utilization of biodiesel by-products for biogas production. J. Biomed. Biotechnol. 2011, 15.

Kosgey, I. S., J. A. M. Van Arendok, and, R. L. Baker. 2003. Economic values for traits of meat sheep in areas of the tropics with medium to high production potential. Small Ruminant Research.50: 187-202.

Kruger, B., and L. Lammerts-Imbuwa. 2008. Training manual: Livestock marketing in Namibia. Windhoek, Namibia: Namibia National Farmers Union.

Kumar, D., C. Datt, L. K. Das, and, S. S. Kundu. 2015. Evaluation of various feedstuffs of ruminants in terms of chemical composition and metabolizable energy content.Veterinary World. 8(5): 605-609.www.veterinaryworld.org/vol.8/May-2015/8.pdf.

Kung, L. 2014. The role of fiber in ruminants in ruminant ration formulation. Department of Animal and Food sciences. University of Delaware.

Larson, E.M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and, D. H. Shain. 1993. Energy value of hominy feed for finishing ruminants. Journal of Animal Science. 71. 1092–1099.

Lashkari, S., and, A. Taghizadeh. 2015. Digestion kinetics of carbohydrate fractions of citrus by-products. Veterinary Research Forum. 6(1): 41-48

Lechner, W. R. 1992. An outline of pearl millet research in Namibia. Proceedings of the First National Workshop on Plant Genetic Resources, Swakopmund, Namibia, 19-21 November 1991. Dinteria, 23.

Lee, J. W., F. K. McKeith, and, H. H. Stein. 2012. Up to 30% corn germ may be included in diets fed to growing-finishing pigs without affecting pig growth performance, carcass composition, or pork fat quality. J. Anim. Sci. 90: 4933–4942.

Lee, J. W., R. Patterson and, T. A. Woyengo. 2018. Porcine in vitro degradation and fermentation characteristics of canola co-products without or with fiber-degrading enzymes. Animal Feed Science and Technology 241, 133-140.

Leibovich, J., J. T. Vasconcelos, and, M. L. Galyean. 2009. Effects of corn processing method in diets containing sorghum wet distillers grain plus solubles on performance and carcass characteristics of finishing beef cattle and on in vitro fermentation of diets. Journal of Animal Science, 87 (6): 2124-2132.

Leng. 1991. Application of biotechnology to nutrition of animals in developing countries. FAO Conference Proceedings, Rome, Italy.

Li, C., J. Q. Li, W. Z. Yang, K. A. Beauchemin.2012. Ruminal and intestinal amino acid digestion of distiller's grain vary with grain source and milling process. Animal Feed Science and Technology 175, 121–130.

Lowell, J. E., Y. Liu, and H. H. Stein. 2015. Comparative digestibility of energy and nutrients in feed ingredients fed to sows and growing pigs. Arch. Anim. Nutr.69:79–97.

Luginbuhl, J. M. and M. H. Poore. 1998. Nutrition of meat goats. Available online at: www.cals.ncsu.edu/an_sci/extension/animal/meatgoat/MGNutr.htm.

Lukomska, N., M. F. Quaas, and S. Baumgärtner. 2014. Bush encroachment control and risk management in semi-arid rangelands. Journal of Environmental Management. 145: 24–34.

Lynch, S. A., A. M. Mullen, E. Oneill, and, C. Alvarez. 2018. Opportunities and perspectives for utilization of co-products in the meat industry. Meat Science. 144: 62-73.

Makkar, H. P. S. 2003. Effects and fate of tannins in ruminant animals, adaptation totannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. Small Ruminant Research. 49: 241-256.

Makkar, H. P. S. 2017. Smart livestock feeding strategies for harvesting triple gain-the desired outcomes in planet, people and profit dimensions: A developing country perspective. Animal Production Science. 56(3), 519–534. https://doi.org/10.1071/AN15557.

Makkar, H. P. S., and, K. Becker. 2009. *Jatropha curcas*, a promising crop for the generation of biodiesel and value-added coproducts. Eur. J. Lipid Sci. Technol. 111: 773–787.

Mehrez, A. Z. and E. R. Ørskov, 1977. A study of artificial fibre bag technique for determining the digestibility of feeds in the rumen. J. Agric. Sci., 88, 645.

Meng, X., and, B. A. Slominski. 2005. Nutritive values of corn, soybean meal, canola meal, and peas for broiler chickens as affected by a multicarbohydrase preparation of cell wall degrading enzymes. Poultry Science. 84: 1242–1251.

Mirzaei-aghsaghali, A., and, N. Maheri-sis. 2008. Nutritive Value of Some Agro-Industrial By-products for Ruminants - A Review. 3(2): 40–46.

Misihairabgwi, J., and A. Cheikhyoussef. 2017. Tradiditional fermented food and beverages of Namibia. Journal of Ethnic Foods. 4 (3): 145-153.tttps://doi.org/10.1016/j.jef.2017.08.001.

Mizubuti, I. Y., E. L. A Ribeiro, E. S. Pereira, E. L. T. Peixoto, E. S. Moura, O. P. P. Prado, V. H. Bumbieris Junior, L. D. F. Silva, and J. M. C. Cruz. 2014. Ruminal degradation kinetics of protein foods by *in vitro* gas production technique. Semina: Ciências Agrárias 35:555-566.

Mlambo, V. and, C. Mapiye. 2015. Towards household food and nutrition security in semi-arid areas: What role for condensed tannin-rich ruminant feedstuffs? Food Research International, Available online at: http://dx.doi.org/10.1016/j.foodres.2015.04.011.

Moate, P. J., S. R. O. Williams, C. Grainger, M. C. Hannah and, E. N. Ponnampalam. 2011. Influence of cold-pressed canola, brewers grains and hominy meals as dietary supplements suitable for reducing enteric methane emissions from lactating dairy cows. Animal Feed Science and Technology.(166-167): 254-264.

Molina-Alcaide, E, and, D. R. Yáñez. 2008. Potential use of olive by-products in ruminant feeding: A review. J. Anim. Sci.147: 247–264.

Moog, F. A. 1998. The role of fodder trees in Philipine smallholder farms. Proceedings of the FAO expert Consultation held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kaula Lampur, Malaysia. Available at http://www.fao.org/DOCREP/003/0632E16.htm

Moorsom, R. 1984. Walvis Bay.Namibia's Port. International Defence and Aid for Southern Africa. London.

Morton, J. F**.** 2007. The impact of climate change on smallholder and subsistence agriculture. PNAS 14:19680-19685

Mourao, J. L., V. M. Pinheiro, J. A. M. Prates, R. J. B. Bessa, L. M. A. Ferreira, C. M. G. Fontes, and, P. I. P. Ponte. 2008. Effects of dietary dehydrated pasture and citrus pulp on the performance of meat quality of broiler chickens. Poultry Science. 87:733-743. Doi:10.3382/ps.2007-00411.

Mpairwe, D. R., E. N. Sabiiti, N. N. Ummuna, A. Tegegne and, P. Osuji. 2003. Integration of forage legumes with cereal crops II. Effect of supplementation with lablab hay and incremental levels of wheat bran on voluntary food intake, digestibility, milk yield and milk composition of crossbred cows fed maize – lablab stover . Livestock Production Science,79: 213–226.

Munarso, S. J. 2010. Detoxification jatropha seed cake in fermentation and its usage to heat the use of corn and soybeans 20 % in feed formulation offers complete with over 15 % fee.

Research Report. Estate Crops Research and Development Centre of Research and Development of the Ministry of Agriculture. Jakarta. Bahasa Indonesia

Mushendami, P., Biwa, B., and, M. Gaomab II. 2008. Unleashing the potential of the agricultural sector in Namibia. Windhoek: Bank of Namibia Research Department.

Mushtaq, T., M. Sarwar, and G. Ahmad. 2009. Influence of sunflower meal based diets supplemented with ex- ogenous enzyme and digestible lysine on performance, digestibility and carcass response of broiler chickens. Animal Feed Science and Technology. 149 : 275–286.

Mwesigwa, R., and, D. Mutetikka. 2013. Performance of growing pigs fed diets based on by-products of maize and wheat processing. 441–446. https://doi.org/10.1007/s11250-012-0237-7

Namibia Census of Agriculture 2013/2014. 2015. Communal Sector Report. Retrieved from https://cms.my.na/assets/documents/NAC_2013.pdf

Namibia National Farmers Union (NNFU). 2006. Farming systems in Namibia. Cape town, South Africa: ABC press.

Namibian Agriculture Marketing and Trade Policy and Strategy October (NAMTPS).2011. Republic of Namibia Ministry of Agriculture, Water and Forestry. www.mawf.gov.na

Nasser, M. E. A. 2009. Effect of partial or complete replacement of cottonseed meal by jojoba meal on gas production, rumen fermentation and produced amylase and carboxymethyle cellulase activity, in vitro. Livestock Research for Rural Development.21 (5) 2009.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th Rev. Edn. Natl. Acad. Sci., Washington, DC.

Ncobela, C. N., A. T. Kanengoni, V. A. Hlatini, R. S. and, M. Chimonyo .2017. A review of the utility of potato by-products as a feed resource for smallholder pig production. Animal Feed Science and Technology. 227: 107–117

Nefzaoui, A.1991. Valorisation des sous-produits de l'olivier. Options Méditerranéennes. Série A. Séminaires Méditerranéens, 16:101-108

Negesse, T., H. P. S. Makkar, and K. Becker. 2009. Animal Feed Science and Technology Nutritive value of some non-conventional feed resources of Ethiopia determined by chemical analyses and an in vitro gas method. J. Anim. Sci. 154: 204–217. https://doi.org/10.1016/j.anifeedsci.2009.09.010

Negesse, T., M. Baysssa, and, S. Benerje. 2016. An *in vitro* assessment of the supplementary effect of concentrates containing graded levels of ground linseed (*Linum usitatissimum*) to household wastes on organic matter degradability, short chain fatty acids, microbial protein , metabolizable energy and relative feed values. Tropical and Subtropical Agriecosystems,19 (2016): 181-191.http.www.redalyc.org/articulo.org?id=93946928008.

Newkirk, R. W., H. L. Classen, T. A. Scott, and, M. J. Edney. 2003. The digestibility and content of amino acids in toasted and non-toasted canola meals. Canada. Journal of Animal Science. 83: 131–139

Njarui, D. M. G. and, J. G. Mureithi. 2004. Forage Production Systems for Dairy Production in the Coastal Lowlands of Kenya. Biomedical and Life Sciences. 195-218.

NRC. 2012. Nutrient Requirements of Swine. 11th Ed. National Research Council, Academy Press. Washington, DC, USA

NRC. Nutrient Requirements of Beef Cattle. updated 7th.ed. Washington, DC:National Academy Press, 2000. 242p

Oliveira, M. D. S., D. A. Mota, J. C. Barbosa, M. Stein, and, F. Borgonovi. 2007. Chemical bromatologic composition and in vitro ruminal digestibility of concentrates containing differents levels of sunflower quacker. Brazilian Animal Science. 8: 629–638.

Oliveira, P. A., R. L. De Oliveira, A. R. Bagaldo, L. R. Bezerra, amd, B. R. Correia. 2016. Intake and digestibility, rumen fermentation, and concentrations of metabolites in steers fed with peanut cake. Tropical Animal Health Prodduction.48:403–409. https://doi.org/10.1007/s11250-015-0965-6

Ondiek, J. O., S. A. Abdulrazak, J. K. Tuitoek, and F. B. Bareeba. 1999. The effects of Gliricidia sepium and maize bran as supplementary feed to Rhodes grass hay on intake, digestion and liveweight of dairy goats. Livestock Production Science. 61:65–70.

Osei, S. A., and, I. K. Twumasi. 1989. Effects of oven-dried cassava peel meal on the performance and carcass characteristics of broiler chickens. Animal Feed Science and Technology.24:247-252.

Otsyina, R. M., B. W. Norton, and, M. Djimde. 2000. Fodder trees and shrubs in arid and semi-arid livestock production systems. 23 Grasslands in Arid and Semi-Arid Regions.http://www.internationalgrasslands.org/files/igc/publications/1997/iii-429.pdf.

Palmquist, D. L., and, T. C. Jenkins. 1980. Fat in lactation rations: review. J. Dairy Sci. 63: 1–14.

Pandey, A, C. R. Soccol, and D. Mitchell. 2000. New developments in solid state fermentation: I-bioprocesses and products. Process Biochem.35:1153–1169. http:// dx.doi.org/10.1016/S0032-9592(00)00152-7.

Papageorgiou, M., and, A. Skendi .2018. Introduction to cereal processing and by-products. sustainable recovery and reutilization of cereal processing by-products. Alexander Technological education Institute of Thessalonik (ATEITh). http://doi.org/10.1016/13978-0-0-102162-0-0-00001-0.

Pearson, L. and J. Langridge. 2008. Climate change vulnerability assessment: Review of agricultural productivity'. CSIRO Climate Adaptation Flagship Working paper No.1. Web-ref http://www.csiro.au/resources/CAF-Working-Papers.

Penner, G. B., P. Yu, and, D. A. Christensen. 2009. Effect of replacing forage or concentrate with wet or dry distillers ' grains on the productivity and chewing activity of dairy cattle. J. Anim. Sci. 153: 1–10. https://doi.org/10.1016/j.anifeedsci.2009.05.006

Preston, T. R. 2007. Better Utilization of crop residues and by-products in animal feeding: research guideline 2. A practical manual for research works. FAO. Animal Production and Health Paper.50: 18-25

Ramchandran, D., S. Moose, K. Low, J. Arp, C. Parsons, and, V. Singh. 2017. Ethanol yields and elevated amino acids in distillers dried grains with solubles from maize grain with higher concentrations of essential amino acids. Industrial Crops and Products. 103:244–250. http:// dx.doi.org/10.1016/j.indcrop.2017.03.049

Rao, A. S., E. S. Monyo, L. R. House, M. H. Mengesha, and, I. Negumbo. 1991. Germplasm collection mission to Namibia. Genetic resources Unite, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India; SADCC/ICRISAT Sorghum and Millet Improvement Program, Bulawayo, Zimbabwe. Genetic Resources Progress Report 67.

Rodriguez, D. A., R. C. Sulabo, J. C. Gonzalez, and H. H. Stein. 2013. Energy concentration and phosphorus digestibility in canola cottonseed, and sunflower products fed to growing pigs. Can. J. Anim. Sci. 93: 493–503.

Rojas, O. J., Y. Liu, and H. H. Stein. 2013. Phosphorus digestibility and concentration of digestible and metabolizable energy in corn, corn co-products, and bakery meal fed to growing pigs. J. Anim. Sci. 91: 5326–5335.

Rose, D. J., G. E. Inglett, and, S. X. Liu. 2010. Utilization of corn (*Zea mays*) bran and corn fiber in the production of food components. J. Sci. Food Agric. 90: 915–924.

Rothauge, A. 2014. Baseline Assessment for the De-Bushing Programme in Namibia. Agricultural Consultant Namibia.

Saha, L. Sonon, D. Hanckock, N. Hill, G. Heusner, and, D. E. Kissel .2017. Common terms used in animal feeding and nutrition. UGA Cooperative Extension Bulletin 1367. Published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state.

Salem, B. and, T. Smith. 2008**.** Feeding strategies to increase small ruminant production in dry environments. Small Ruminant Research.**77**: 174-194.

Salim, H., K. M. Wood, P. L. Mcewen, G. Vandervoort, S. P. Miller, I. B. Mandell, and, K. C. Swanson. 2014. Influence of feeding increasing level of dry or modified wet corn distillers grains plus solubles in whole corn grain-based finishing diets on growth performance , carcass traits , and feeding behavior in finishing cattle. Livestock Science. 161:53–59. https://doi.org/10.1016/j.livsci.2013.12.020

Sanon, H. O. 2007. The importance of some Sahelian browse species as feeds for goats. PhD Diss. Swedish University of Agricultural Sciences.Uppsalla.

Sanon, H. O., C. Kabore-Zoungrana, and, I. Ledin. 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area. Small Ruminant Research. 67: 64-74.

Sansoucy, R., X. Alibes, P. H. Berge, F. Martilotti, A. Nefzaoui, and, P. Zoïopoulos. 1985. Los Subproductos del olivar en la alimentación animal en la cuenca del Mediterráneo. Producción Sanidad Animal 43. FAO Roma (Italia) 46 pp

Schroeder, J. W. 2012. Corn Gluten Feed: Composition, Storage, Handling, Feeding and Value. North Dakota State University Fact Sheet AS-1127.Educational.

Schröter, M., O. Jakoby, R. Olbrich, M. Eichhorn and, S. Baumgärtner. 2009. Remote sensing of bush encroachment on commercial cattle farms in semi-arid rangelands in Namibia. University of Lüneburg. Working Paper Series in Economics No. 131.

Sikosana, J. L. N., V. Maphosa, T. Smith, E. Owen and, I. Mueller-Harvey. 2002a. Use of local browse tree pods as dry season supplements for goats in the south-west region of Zimbabwe. In: Responding to the increasing global demand for animal products; an international Conference organized by the British Society of Animal Science (BSAS), American Society of Animal Science andthe Mexican Society of Animal production, 12-15 November 2002 at UADY Merida. BSAS.pp193

Silanikove, N., A. Perevolotsky, and, F. D. Provenza. 2001. Use of tannin-binding chemicals to essay for tannins and their negative postingestive effects in ruminants. Animal Feed Science and Technology.91: 69-81.

Silva, A. M. A., A.V. Alves, L.R. Bezzera, H. Carneiro, R. L. Oliveira, F. F. Medeiros, J. P. Preira, D. R. C. Araujo. 2015. Potential in vitro degradability and gas production of the by-products of biodiesel chain.Cien.inv.Agr.42:285-293.

Sindhu, A. A., M. A. Khan, Mahr-Un-Nisa and, M. Sarwar. 2002. Review Agro-Industrial By-Products as a Potential Source of Livestock Feed. International Journal of Agriculture & Biology. 8530: 4–2. Retrieved from http://www.ijab.org

Singh, K. S., and, C. M. Prasad. 1979. Feeding value of sunflower and groundnut cakes for broilers. J. Anim. Sci. 4:143-159.

Smith, T. 2007, August). Byproducts of ethanol industry can vary based on type of production, source and individual load. Hereford World, 34. Retrieved August 30, 2018, from www.hereford.org

Sol, C., L. Castillejos, and, J. Gasa. 2017. Prediction of the digestibility and energy contents of non- conventional by-products for pigs from their chemical composition and in vitro digestibility. Animal Feed Science and Technology. 234: 237–243. https://doi.org/10.1016/j.Animal nifeedsci.2017.10.003.

Soren, N. M., and V. R. B. Sastry .2009. Replacement of soybean meal with processed karanj (Pongamia glabra) cake on the balances of karanjin and nutrients, as well as micro- bial protein synthesis in growing lamb. Animal Feed Science and Technology 149: 16–29.

Soy and Oilseed Blue Book. 2015. Annual Directory of the World Oilseed Industry Soyatech LLC. Southwest Harbor, Maine, USA, 04679.

Spanghero, M., A. Nikulina, and F. Mason. 2018. Use of an in vitro gas production procedure to evaluate rumen slow-release urea products. Anim. Feed Sci. and Technol. 237 1:9–26. https://doi.org/10.1016/j.ani feed sci.2017.12.017.

Spiehs, M. J., and V. H. Varel. 2009. Nutrient excretion and odorant production in manure from cattle fed corn wet distillers grains with solubles. Journal of Animal Science.87: 2977–2984.

Statistical Software for Social Sciences (SPSS). 2010. IBM SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp.

Stefanello, F. S., C. O. Sontos, V.C. Boch., A. P. B Fruet, M. B Soquetta, A. C. Dorr , and, J. L. Norberg. 2018. Analysis of polyphenols in brewer’s spent grains and its comparison with corn silage and cereal brans commonly used for animal nutrition. Food Chemistry. 385-401.htttp://dx.doi/10.1016/j.foodchem.2017.06.130.

Stein, H. H. and G. C. Shurson. 2009. Board-invited review: the use and application of distillers’ dried grains with solubles in swine diets. Journal of Animal Science. 87: 1292–1303.

Stein, H. H., L. V. Lagos, and G. A. Casas. 2016. Nutritional value of feed ingredients of plant origin fed to pigs. Animal Feed Science and Technology. 218: 33–69. https://doi.org/10.1016/j.anifeedsci.2016.05.003

Sweet, J. 1998. Livestock coping with drought: Namibia- A case study. Nothern regions livestock development project, Tsumeb, Namibia.

Sweet, J. and A. Burke., 2006. Country Pasture/Forage Resource Profiles. Available online at: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Namibia/namibia.htm.

Sweet, J., and A. Burke. 2006. Country Pasture/Forage Resources Profiles. URL:http://www.fao.org/ag/AGPC/doc/Counprof/Namibia/namibia.htm. Accessed on 12 September 2018.

Swiatkiewicz, S., A. Arczewska-wlosek, and, D. Jozefiak. 2014. Feed enzymes , probiotic , or chitosan can improve the nutritional efficacy of broiler chicken diets containing a high level of distillers dried grains with solubles. Livestock Science.163:110–119. https://doi.org/10.1016/j.livsci.2014.03.001

Tagliapietra, P. F., M. Cattani, L. Bailoni, and S. Schiavon. 2010. *In vitro* rumen fermentation: effect of headspace pressure on the gas production kinetics of corn meal and meadow hay. Anim. Feed Sci. Technol. 158:197-201.

Talbot, A.M. 1970. South West Africa (Namibia). World Atlas of Agriculture (Africa) 4:590-619.Technology. 129:279–303.

Thi, N. B. D., G. Kumar, and, C. Y. Lin. 2015. An overview of food waste management in developing countries: Current Status and Future perspective. Journal of environmental management. Http://dx.doi.org/10.1016/j.env man.2015.04.022.

Thieme, O., and H. P. S. Makkar. 2017. Utilisation of loss and waste during the food-production cycle as livestock feed. Animal Production Science.57: 601–607. https://doi.org/10.1071/AN16183

Tilley, J. M. A. and R. A. Terry, 1963. A two-stage technique for the digestion of forage crops. J. Br.Grassl. Soc., 18, 104.

Tokach, M., R. Goodband, and J. De Rouchy. 2012. Sorghum in Swine Production. Feeding Guide. United Sorghum Checkoff Program.http://sorghumcheckoff.com/wp-content/uploads/2012/06/swineguideforweb.pdf.

Topps, J. H. 1992. Potential composition and use of legume shrubs and trees as fodder for livestock in the tropics (Review). Journal of Agricultural Science. 118: 1-8.

Topps, J. H. and, W. Z. Mohamed.1979. Pot ale syrup as a protein-supplement for cattle. Journal of Animal Production, 28: 430-439.

Trade Policy Framework: Namibia. 2016. United Nations Conference on Trade and Development (UNCTAD). UNITED NATIONS, Newyork and Geneva. Retrieved from www.unctad.org/tradenegotiations

Tshabalala, T., J. L. N. Sikosana, and, E. Chivandi. 2013. Nutrient intake, digestibility and nitrogen retention in indigenous goats fed on *Acacia nilotica* fruits treated for condensed tannin. South African Journal of Animal Science. 43: 457-463.

Unated Nations Environment Prpgramme. 2012. Green Economy Sectoral Study. BioTrade-A cataylist for transitioning to green economy in Namibia. Doi:10.13140/RG.2.2.31705.2601

Ugwuanyi , J.O. 2016.Agro-Industrial Wastes as Feedstock for Enzyme Production. Chapter 10. 233- 260. http://dx.doi.org/10.1016/B978-0-12-802392-1.00010-1.

Van Saun, R. J. 2013. Determining forage quality: Understanding feed analysis. Penn state Extension. Accessed on 10 march 2019 from https://extension.psu.edu

Van Soest P. J. (Editor), 1994. Nutritional Ecology of the Ruminant.Cornell University Press. Ithaca, NY (USA)

Verbiscar, A. J. 1978. Composition of Jojoba seeds and foliage. J. Agric Food Chem.26:1456–1459.

Verbiscar, J. A., and, T. A. Banigan .1982. Jojoba meal as a livestock feed. Pp. 267-280 in Jojoba and its Uses. Through 1982,Proceedings of the Fifth International Conference, Anna Elias-Cesnik, ed. University of Arizona, Tucson, Arizona.

Vermaak, I., G. P. P. Kamatou, B. Komane-Mofokeng, A. M. Viljoen and K. Beckett. 2011. African seed oils oof commercial importance-cosmetic applications. South African Joutnal of Botany. 77: 920-933. Doi: 10.1016/j.sajb.2011.07.003.

Wadhwa M, Bakshi MPS, Makkar H. P. S .2016.Waste to worth: vegetable wastes and by-products as animal feed. CAB Reviews 11,1–26. doi:10.1079/PAVSNNR201611012

Wahlberg, M. 2009. By-Product Feeds - Wet Corn Milling. Virginia: Virginia Cooperative Extension. Retrieved August 31 , 2018, from http://sites.ext.vt.edu/newsletter-archive/

Ward, D. 2005. Do We Understand the Causes of Bush Encroachment in Africa Savannas? Africa Journal Range and Forage Science, 22:101-105.

Welker, T. L., C. Lim, F. T. Barrows and, K. Lin. 2014. Use of distillers dried grains with solubles (DDGs) in rainbow trout feeds. Animal Feed Science and Technology. 195: 47-57.

Wenk, C. 2001. The role of dietary fibre in the digestive physiology of the pig. Animal Feed Science and Technology .90: 21–33

Whittemore, C. T. 1977. The potato (*Solanum tuberosum*) as a source of nutrients for pigs: calves and fowl—a review. Animal Feed Science and Technology. 2: 171–190.

Widiyastuti ,T. T. R. Sutardi, and, M. Indradji.2012.Optimalitation of jatropha seed cake protein concentrate as rabbit feed through chemical and biological using lactic acid bacteria. Laporan Penelitian Riset Unggulan Tahun . Fakultas Peternakan, UNSOED. Purwokerto. Bahasa Indonesia.

Wood, K. H. Salim, P. McEwen, I. Mandell, S. P. Miller, and, K. Swanson. 2011. The effect of corn or sorghum dried distiller's grains plus solubles on growth performance and carcass characteristics of cross-bred beef steers. Animal Feed Science and Technology. 165: 23-30.

Wyngaard, J. D., V. Van, R. Meeske and, L. J. Erasmus. 2015. Effect of palm kernel expeller as supplementation on production performance of Jersey cows grazing kikuyu-ryegrass pasture. Animal Feed Science and Technology. 199: 29–40. https://doi.org/10.1016/j.anifeedsci.2014.10.017

Yadav, M. P., Hicks, K. B., Johnston, D. B., Hotchkiss, A., Chau, H.K., Hanah, K. 2015. Production of bio-based fiber gums from the waste streams resulting from the commercial processing of corn bran and oat hulls. Food Hydrocoll. 10

Yaron, G., G. Janssen, and, U. Maamberua. 1992. Rural Development in the Okavango Region of Namibia: an assessment of needs, opportunities and constraints. Gamsberg Macmillan Publishers, Windhoek.

Yoon, J., Stein, H. H. 2013. Energy concentration of high protein low-oligosaccharide, and conventional full fat de-hulled soybeans fed to growing pigs.Animal Feed Science and Technology. 184, 105–109.

Zaidi, F., N. Hassissene, N. Bobekeur, A. Bouaiche, A. Bouabdella, J. Grongnet, M. M. Bellal, and, A. Youyou.2008. Etude in vitrode facteurs limitant la valeur nutritive du grignon d'olive: effets des matières grasses et des métabolites secondaires. Livestock Resources and Rural Development, 20 (3).

Zaza, A. I. A., 2008. Performance of Awassi Lambs fed citrus pulp and olive cake silage. Faculty of graduate studies .An Najah National University, Nablus, Palestine, p. 1-18.

Zentek, J. F. A. Knorr, A. Mader and, F. U. Berlin. 2014. Reducing waste in fresh produce processing and households through use of waste as animal feed. Global safety of fresh produce: A handbook of best practice, innovative commercial solutions and case studies. Woodhead Publishing Limited. https://doi.org/10.1533/9781782420279.2.140.

Zhou, X., E. J. Beltranena, and, R. T. Zijlstra. 2016. Effects of feeding cattle canola press-cake on diet nutrient digestibility and growth performance of weaned pigs. J. Anim. Sci.211: 208-2015.http://dx.doi.org/10.1016/j.anifeedsci.2015.12.001.

Zilic, S., B. A. Mogol, G. Akillioglu, A. Serpen, M. Babic, and, V. Gökmen. 2013. Effects of infrared heating on phenolic compounds and Maillard reaction products in maize flour. Journal of Cereal Science. 58: 1–7.

zu Ermgassen, E. K. H. J., B. Phalan, R. E. Green, and A. Balmford. 2016. Reducing the land use of EUpork production: where there's a will, there's a way. Food Policy 58, 35–48. doi:10.1016/j.foodpol.2015.11.001

APPENDIXES

1. SURVEY ADVERT

2. SURVEY QUESTIONNAIRE

THE IDENTIFICATION AND QUANTIFICATION OF AGRO-INDUSTRIAL BY-PRODUCTS IN NAMIBIA

SURVEY QUESTIONNAIRE

This survey is voluntary and the information that you give will be treated in absolute confidentiality. It will be used to prepare reports and inform policy, but will not include any specific names. There will be no way to identify that you gave this information without your prior consent. Your time in filling this questionnaire will be highly appreciated and valued.

SECTION 1: ENTERPRISE DEMOGRAPHICS

1.1 Contact information

Enterprise Name:…………………………………………………………………………

Enterprise Location: ……………………………………………………………………..

Enterprise size (large /medium/ small scale): …………………………………………

Email Address: …………………………………………………………………………..

Phone Number: ………………………………………………………………………….

SECTION 2: MAIN PRODUCTS AND BY-PRODUCTS FREQUENCIES

2.1 What product (s) do the firm/ project/enterprise produce?

1…………………………………..

2 …………………………………..

3……………………………………

2.2 What kind of by-products/ wastes do you produce?

- Cereal grains milling by-products (e.g. rice bran, wheat bran, rice husks, etc.)
- Oil production by-products (e.g. oilseed cakes, hulls)
- Pulses milling by-products (cowpea bran, etc.)
- Brewery and malt factory by-products (e.g. dry distillers)
- Winery by-products (e.g. grape pomace)
- Juice industry by-products (e.g. guava juice cake, mango peels etc.)
- Food industry by-products (tomato pulp, potato peels etc.)
- Sugar factory by-products (molasses, pulp etc.)
- Horticultural/fruits and vegetables by-products (potato straw, tomato vegetable waste etc.)
- Others

2.3. How **often do you produce these by-products /wastes? (Write the names of the by-products and make a cross (X) in the appropriate boxes)**

By-product name	Daily	Weekly	Monthly	Quarterly	Yearly
1.					
2.					
3.					
4.					

2.4. How much by-products do you produce? (Add units to the quantity e.g. Kg, tones,)

By-Product	Daily (quantity)	Monthly (quantity)	Annually (quantity)
1.			
2.			
3.			
4.			

2.5. Which months of the year do you have by-products available?

By-product name	Month (s) of production
1.	
2.	
3.	
4.	

2.6. In what form are the by-products you produce? (Write the names of the by-products and make a cross (X) in the appropriate boxes)

By-Products name	Wet	Dry	Wet and Dry
1.			
2.			
3.			
4.			

SECTION 3: BY-PRODUCTS MANAGEMENT

3.1. What happens to the by-products you produce? (Write the names of the by-products and make a cross (X) in the appropriate boxes)

By-product	Repro cessed	Used to make fertilize r	Discarde d	Burn ed	Sold	Given away for free	Others (specify)
1.							
2.							
3.							
4.							

3.2. Do you have a place where you keep your by-products?

Yes	No

3.3. Will storage be challenging in case of commercializing your by-products?

Yes

No

Only partially

3.3. How long do you keep the by-products on the production site? (Write the names of the by-products and make a cross (X) in the appropriate boxes)

By-product	One day	Two days	A week	A monthly	Others please specify
1.					
2.					
3.					
4.					

SECTION 4: BY-PRODUCTS PRESERVATION AND PACKAGING

4.1. How do you preserve the by-products?

Name of the by-product	None	Freezing	Drying	Other methods (specify)	Packaging			
1.					Yes		No	
2.					Yes		No	
3					Yes		No	
4.					Yes		No	

SECTION5. BY-PRODUCTS MARKETING

5.1. What are the prices of the by- products that are sold?

By-product	Price per quantity (e.g. 1N$/1 Kg)

1.	
2.	
3.	
4.	

5.2. Which ones are your marketing channels of your by-products?

- Wholesaler
- Retailer
- Agent
- Directly to consumers (e.g. farmers)

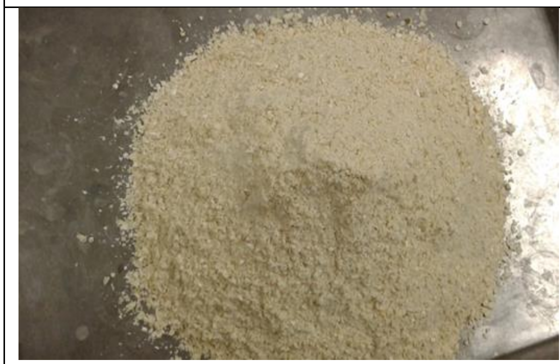
5.3. Which are your major customers?

- Retailers (e.g. AGRA, FeedMaster, KaPAgri)
- Agents
- Commercial farmers
- Communal farmers

SECTION 6: CONTAMINATIONS

6.1. Is there any possible contaminants or components contained in the by-products you produce that can be a problem to animals consuming it? (E.g. mycotoxins, manure, chemicals etc.)

By-product name	Possible contaminant (s)
1.	
2.	
3.	
4.	

CEREAL BY-PRODUCTS	Description	Company name	
 **By-product name**: White maze chop	A by-product of white maize milling for flour products production	BOKOMO Mills	

 **By-product name**: Malt dust coarse	A by-product of beer production.	NamibainBreweries Ltd,	Windhoek: Khomas region.
 **By-product name**: Malt dust fine	A by-product of beer production.	NamibainBreweries Ltd,	Windhoek: Khomas region
 **By-product name**: Pearl Millet Bran	a by-product of pearl millet grains milling from	Punikwa Trading Factory	Windhoek: Khomas region.

 **By-product name**: Pearl Millet Bran	a by-product of *Omalodu iilya* ,a traditional beverage	Punikwa Trading Factory	Windhoek: Khomas region.
 **By-product name**: Brewer's Spent Grains	a by-product of beer production from	NamibianBreweriesLimited	Windhoek: Khomas region
OIL SEED BY-PRODUCTS	Description	Company Name	Location

 **By-product name:** Olive oil cake	a by-product of olive oil extraction	Namib Desert Jojoba Oil Producers cc	Swakopmund
 **By-product name:** Marula Oil press	a by-product of marula oil extraction from marula kernels	Taneta Trading CC	Windhoek
 **By-product name:** Jojoba oil cake	a by-product of jojoba oil extraction a by-product of oil	Namib Desert Jojoba Oil Producers cc Namib Desert Jojoba Oil Producers cc	Swakopmund Swakopmund

 **By-product name:** Marula oil cake	extraction from Marula tree seed kernels		