ASSESSMENT OF CHEMICAL COMPOSITIONS OF GRAINS AND FODDERS OF SELECTED CROPS CULTIVATED USING IRRIGATION-FED FARMING IN KUNENE REGION, NAMIBIA

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Abstract

This study has the main objective of assessing the chemical compositions of grains and fodders harvested from maize, sorghum, cowpea, Okashana and Kangara (pearl millet varieties) cultivated under experimental irrigation-fed farming at Otuzemba and Swartbooisdrift in Kunene Region. The following chemical compositions: moisture levels, ash contents, crude protein, fat content, crude fibre, carbohydrate content, mineral elements (phosphorus, calcium and potassium), were analyzed in the grains and fodders. Additionally, dry matter, acid detergent fibre, neutral detergent fibre, and acid detergent lignin were determined in the fodders. All the laboratory analyses were performed using standard laboratory procedures at the Ministry of Agriculture's Analytical Laboratory, Windhoek. The results obtained revealed that the grains' moisture levels, ash contents, crude protein, fat content, crude fibre, and carbohydrate content at both experimental farms fall within the standards grain values of l < 12%, 1.2% to 5.4%, 7% to 15%, 1.5% to 5.6%, 1.4% to 3.7%, and 63% – 79% respectively. Apart from Okashana and Kangara which recorded low levels of calcium and phosphorus, the other grains (maize, cowpea and sorghum) recorded optimum levels of all the mineral elements (calcium (0.021% to 0.38%), phosphorus (0.01% to 0.368%), and potassium (0.009% to 2.9%) determined in the present study. Furthermore, the results of the different chemical compositions analyzed in the fodder samples fall within the standard values recommended for animal feeds. The research findings are indicative of the prospect of quality grain and fodder production using irrigation – fed farm in the study area as all the crops cultivated in this study could produce edible grains and fodder for human and livestock nutrition respectively.

Key words: Nutritional value, Composition, Kunene Region, Fodder, Food, Production.

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1. Introduction

The main objective of this study is to assess the chemical compositions of grains and fodders of selected crops (maize, sorghum, cowpea and pearl millet (Kangara and Okashana) cultivated under experimental irrigation-fed farming at Otuzemba and Swartbooisdrift in Kunene Region of Namibia. Being one of the worst drought affected regions in Namibia, Kunene Region depends largely on livestock production for its livelihoods, but the lack of adequate rainfall to support viable rain-fed production of livestock feeds has necessitated a shift towards irrigation-fed farming to produce feed, especially grains and fodders which can be grown in the region. In a study report by Rothauge (2016), it was noted that there is no amount of rainfall in the world that will be able to optimally recover the pasture of Kunene Region within meaningful time. In fact, the persistence drought in Kunene Region has brought and is still bringing pressing issues related to human and livestock food insecurity both to the residents and the Namibian government (Sanchez, 2002; Bationo *et al*, 2007). Thus, finding alternative method of cultivating crops such as maize, sorghum, cowpea and pearl millet which can produce both grains and fodders for human and livestock consumption respectively can be a wise step towards improving food security in the drought-ravaged Kunene Region of Namibia.

Interestingly, crops produced under irrigation-fed farming have produced high yield even in semi-arid to arid regions despite adverse weather conditions (Tilahum *et al*, 2011). According to Amole et al. (2021), irrigated farming as a supplement to rain-fed farming has been recommended to increase cropping intensity, as well as crop and fodder productivity. Pasture irrigation has been described as a promising technique that increases forage resource availability (Arya et al., 2011), and livestock productivity by maintaining forage crops during periods of drought, which is reflected in livestock production (Ferreira et al., 2020; Mochel et al., 2016). Thus, with the available perennial river in the Kunene Region, a well–developed irrigation system could successfully supplement the low annual rainfall received in the region and boost food and animal fodder production.

According to Malla (2004), fodder crops provide nearly 40% of the total annual feed requirement of the ruminants. Fodder plays a key role in ruminant feeding as basal component of animal diet and variations in its quality have direct effect on digestive functionality, concentrate supplementation, animal performance and health (Chakravarthi et al., 2017). According to Geng et al. (2020), achieving higher livestock productivity requires improvement in feeding programs with the aim of meeting the nutritional requirements of livestock through a balance of feed ingredients. Similarly, Karunanayaka (2020) asserted that the most indispensable and basic input for efficient livestock production is the good quality fodder. For this purpose, Geng et al. (2020) opined that it is essential to have access to detailed data regarding the nutrient compositions of feed ingredients.

Currently, majority of the available data on nutritive value of fodder species is limited to chemical compositions and minerals (Le Houérou, 1980). Research reports in different literature show variable chemical compositions among various fodder species ranging from 35-60 g/kg dry matter, 107-300 g/kg ash, 154-511 g/kg crude protein, 14- 396 g/kg neutral detergent fiber (NDF), and 51-206 g/kg acid detergent fiber (ADF) (Sawe et al.,1998; Abdulrazak et al., 2000; Rubanza et al., 2003). Availability of quality feed determines livestock's ability to produce optimally within their genetic limits (Coleman & Moore, 2003). Thus, an assessment of the nutritional quality and chemical compositions of available fodder can help to identify potential livestock nutritional deficits that must be addressed to provide a balanced diet that helps to maintain a healthy livestock production system. Fodder quality can be assessed using fodder dry matter, crude proteins, and minerals as indicators (Moreira, 1989, Lounglawan et al., 2014). Therefore, the objective of this study is to evaluate chemical compositions and nutrition values of selected fodders grown using irrigation-fed farming in two experimental sites in the Kunene Region, Namibia.

2. Materials and Methods

2.1 Study area

The trials were conducted in Kunene Region located on latitude 19.4086° S and longitude 13.9144° E in the North – western part of Namibia. The experimental farms were established in two locations – Otuzemba (-18.5262° S, 14.1146° E) and Swartbooisdrift (17.3336° S, 13.8366° E) in the region. The selected localities are endowed with

abundant perennial water sources that could be utilized for irrigation purposes sustainably. Kunene Region has an estimated 88 300 total populations (Census, 2011), who are predominantly farmers. The area is one of the driest regions in Namibia receiving less than 300 mm rainfall per annum (Sweet & Burke, 2000). The devastating drought suppressed both crop and livestock production in the region, as the rain – fed farming method was no longer a reliable cropping method due to the low rainfall received and high temperature prevailing in the region. Therefore, irrigation cropping method which does not rely on rainfall becomes a necessity in this region. Under irrigation farming, the crop's water need is sufficiently supplied unlike the rain – fed agriculture where rainfall water is sometime insufficient to meet the crop's water requirement (Getnet *et al, 2016)*. In fact, according to Tilahum *et al*, (2011), irrigation removes dry periods experienced under rain – fed cropping method.

2.2 Sample collection

All the samples were collected after physiological maturity was reached (Devendra & Thomas, 1997) in May, 2019. Each crop grain samples were collected from 5 selected plant stands per plot measuring 12 m^2, using stratified random sampling. The crop fodder samples were similarly collected using clipper – cutting to harvest the forage (stem and leaves without roots) at 10 cm above the ground. Each crop grain and fodder samples were mixed thoroughly and a representative sample taken for laboratory analysis (Rusche, 2019). All the grain and fodder samples were labelled properly with crop name and farm location to avoid cross – contamination.

2.3 Sample preparation and analysis

All the sample preparations and analyses were performed at the Analytical Laboratory, Ministry of Agriculture, Water and Land Reform in Windhoek. All the grain and fodder samples were shaken by hand to remove adhering soil particles as much as possible, dried at 65 °C in a forced-air oven, and ground to pass through 1 mm mesh sieve (Devendra & Thomas, 1997).

2.3.1 Crude Protein

Crude protein of each sample was determined using Dumas nitrogen – protein determination method. The sample was first homogenized, weighed to 1g and then heated in a high temperature furnace rapidly through combustion process at 950 °C in the presence of pure oxygen and then purged of any atmospheric gases (Mæhre *et al*, 2018). The gas mixture (water, carbon dioxide and nitrogen oxides) produced were passed through reduction chamber containing copper, heated at 650°C to remove oxygen and convert nitrogen oxides into molecular nitrogen (Mæhre *et al*, 2018). Then, the sample was further passed through traps that remove water and carbon dioxides after which the nitrogen content was measured using thermal conductivity detector (Goering & Van Soest, 1970). The measured signal is proportional to the nitrogen content (%) of the analyte, and the nitrogen was converted to Crude protein using the relation (Mæhre *et al*, 2018):

Crude protein % = N x 6.25 ---------- Eq. 1

2.3.2 Crude Fibre

Crude fibre content of each sample was determined following the Association of Official Analytical Chemists procedure (AOAC, 1995). For each sample, 1 g of the dried, ground and sieved (< 1mm mesh) powder was weighed into a marked crucible. The crucible was placed in a hot extraction unit and locked properly to digest for 4 hours. All the valves of the extraction unit were closed and cooling water was turned on to flow at 1 – 2 dm^3 per minute. Then, 150 cm^3 of preheated (95 ºC) sulphuric acid solution was added to the crucible using a funnel followed by the addition of 3 drops of *n* – octanol (antifoaming agent). The heating element was turned on and the crucible was heated to bring the contents to boiling for 30 minutes. Then, water suction pump was started while the valve was turned on to vacuum position. Each sample was rinsed 3 times with about 30 cm^3 of hot distilled water each time, and all adhering materials were rinsed off the wall of the tube. With the valves of the water suction pump maintained at closed positions, 150 cm^3 of preheated (95 ºC) sodium hydroxide solution was added to the crucible followed by the addition of 3 drops of *n* – octanol. Then, the contents were heated to boiling for 30 minutes (AOAC, 1995).

The heating element was turned off, and each crucible content was filtered by vacuum, rinsed 3 times using 30 cm^3 of hot distilled water each time as done earlier. The filtrate was washed 3 times with about 20 cm^3 of acetone (to remove traces of water) and the water suction pump was closed while the

valves were turned off. The crucibles were removed using safety hook, placed in a drying oven and dried overnight at 105ºC. Then, the crucibles were cooled in a desiccator for 30 minutes and weighed (W_1). Thereafter, the crucibles were transferred into a cool furnace; the temperature was adjusted to 500ºC and the crucibles' contents were ashed at this temperature for 4 hours. Then, the crucibles were allowed to cool slowly to below 250℃ before being removed from the furnace and placed in a desiccator to cool further for 30 minutes, and weighed again (W_2). The crude fibre was calculated using the following relations:

$$Crude\ fibre\ (\%) = \frac{W_1 - W_2}{m} \times 100$$ ----------Eq. 2

Where:
- ➢ W_1 = Mass of residue in crucible after drying, in g
- ➢ W_2 = Mass of residue in crucible after ashing, in g
- ➢ m = Original sample mass, in g

2.3.3 Calcium

The phosphorus levels in the grain and fodder samples were determinec the AOAC method (AOAC, 1995) following A measured 1 g of each ground, sieved (< 1mm mesh) fodder sample was quantitatively transferred into a marked 80 cm^3 porcelain crucible. The crucible was placed in a muffle furnace and ashed at 550ºC overnight. Then, the crucible was removed, cooled in a desiccator and then placed in a boiling water bath. Then, 3 cm^3 of deionised water was added to the crucible followed by the addition of 5 cm^3 concentrated hydrochloric acid. The sample was evaporated slowly to dryness on the boiling water bath and heated further for 30 minutes. Then, 20 cm^3 deionised water was added followed by the addition of 3 cm^3 of concentrated HCl to wet the residue. The sample was then heated for 5 minutes and filtered through Whatman No. 4 filter paper into a 50 cm^3 volumetric flask. The filter paper was washed thoroughly with hot (70 ºC) deionised water, and the filtrate was cooled and made up to volume with deionised water.

Then, 5.0 cm^3 of the sample solution, 20 cm^3 deionized water, 2 cm^3 magnesium solution, and 10 cm^3 *NaOH* solution were added to a 250 cm^3 Erlenmeyer flask. A calculated excess of standardized 10.0 cm^3 EDTA solution with small amount of Ca – red indicator powder was added. A small magnetic stirrer was placed in the flask and the content was titrated against prepared standard calcium solution until the end point marked by colour change from blue – green to blue – red. With each analysis, two titration blanks were done using the solutions but without adding the sample solution. Calcium level calculation was carried out using the formula below (AOAC, 1995).

$$Ca\ (g\ kg^{-1}) = \frac{(Ts - Tb) \times Vt \times C}{1000 \times Va \times m}$$ ---------- Eq.3

where:
- ➢ T_S = Titration volume of sample
- ➢ T_b = Titration volume of blanks
- ➢ V_t = Total volume of sample solution (here 50 cm^3)
- ➢ V_a = Volume of the aliquot taken for analysis (here 5.0 cm^3)
- ➢ C = Calcium concentration (here 200 mg dm^{-3})
- ➢ *1000* = Conversion of 1 mg into g
- ➢ m = Sample mass, in g

$$Calcium\ (\%) = \frac{Ca\ (g\ kg^{-1})}{10} \times 100$$ ---------- Eq. 4

2.3.4 Phosphorus

The phosphorus level in the grain and fodder samples was measured using spectrophotometer following colorimetric procedure (AOAC, 1995). For each sample, 1 g of the dried, ground and sieved (< 1mm mesh) sample was weighed into volumetric flask (50cm^3). Then, standard solution of acid mixture of (HNO_3 + H_2O_2 + HF), as well as

1mg/cm^3 and 0.5µg/cm^3 of phosphorus was prepared, transferred into 100cm^3 volumetric flask and the volume was made up to the mark with deionized water. Then, 10cm^3 of the solution was transferred into the 50cm^3 volumetric flask using pipette, followed by the addition of 5cm^3 of 5M hydrochloric acid and 5cm^3 of molybdate – ammonium metavanadate. The solution was diluted to 50cm^3 and allowed to settle for 30 minutes. Thereafter, the sample solution was taken in a 10mm optical cell and the absorbance was measured spectrophotometrically at 400nm, and standard curve of phosphate absorbance against concentration was constructed (AOAC, 1995). Using the readings from the standard graph of the concentrations of the sample and the blank, the differences between the sample and blank concentrations were calculated. Thereafter, phosphorus concentration was calculated using the following formula (AOAC, 1995):

$$P\ (mg\ kg^{-1}) = \frac{C_g \times V \times 50}{10 \times m}$$ ---------- Eq. 5

Where:

- C_g = Difference between the sample and blank concentrations as read from the graph, in μg/cm^3
- V = Total volume of the sample digest solution, (here 100 cm^3)
- m = Mass of the sample, in g
- 10 = Sample aliquot (here 10cm^3)
- 50 = Dilution of sample aliquot (10 cm^3) to 50 cm^3.

2.3.5 Fat content

Soxhlet extraction method was used to extract the fat content in the samples following the AOAC (1995) procedure. A measured amount, 2 g of the ground and sieved sample was transferred into a filter paper. The filter paper was carefully folded to completely encapsulate the sample. An empty Soxhlet extraction flask was cleaned, weighed, dried at 105 ºC and then filled to about 2/3 of its capacity with petroleum ether. Thereafter, the flask was placed on a heating mantle and then connected to the extraction apparatus and the thimble containing the sample was placed in the extractor. To ensure that the sample was properly immersed in the petroleum ether, it was pushed down the thimble and secured in place using a cotton wool plug which was inserted in the thimble. Then, the temperature of the heating mantle was adjusted to 60 ^{o}C to heat the petroleum ether to boiling and the heating was continued for 4 hours at condensation rate of 5 to 6 drops of ether per second (AOAC, 1995). Thereafter, the thimble was removed and the ether was distilled into the collection tube for re–use purposes. The flask was carefully removed from the heating mantle before complete evaporation of ether (AOAC, 1995) and placed in a cold explosion–proof oven to cool. The flask was then removed after 1 hour from the oven and cooled further in a desiccator and weighed. The crude fat calculation was then carried out as follow:

$$Crude\ fat\ (\%) = \frac{MFR - MF \times 100}{m}$$ ---------- Eq. 6

Where:

- MFR = Mass of flask with extracted residue, in g
- MF = Mass of flask, in g
- m = Mass of sample used, in g

Petroleum ether is a highly flammable solvent therefore; safety measures were applied. Thus, the area where the extraction took place was well ventilated for removal of the ether vapours. The drying oven used was explosion – proof and installed in a well–ventilated fume cupboard. Open flames were not allowed in the area of the extraction apparatus (AOAC, 1995).

2.3.6 Total Ash

The AOAC (1995) method for the determination of total ash in plant samples was used. A pre–dried crucible was weighed empty and the mass was recorded as W_1. Then, 2g of the ground and sieved (< 1 mm sieve) sample was transferred into the crucible and the mass of the crucible plus content was weighed and recorded as W_2. The crucible with contents was placed in a cool muffle furnace and the

temperature was set at 250°C for 1 hour and then raised to 550°C to ash the sample for 4 hours (AOAC, 1995). The sample was then cooled in the desiccator and the mass was weighed and recorded as W_3. The following formulae were used to calculate the ash.

$$Total\ Ash\ (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$ ---------- Eq. 7

Where;
- ➢ W_1 is the mass of pre – dried empty crucible,
- ➢ W_2 is the mass of sample plus crucible, and
- ➢ W_3 is the mass of sample plus crucible after ashing

2.3.7 Dry Matter and moisture

The Dry Matter content of each fodder sample was determined by drying the sample and measuring the water loss (Devendra & Thomas, 1997). An aluminium dish was weighed empty (W_1) and 2g of the ground and sieved (< 1 mm sieve) sample was transferred into the aluminium dish. Then the sample plus the aluminium dish was weighed as W_2. The aluminium dish containing the sample was placed in a vacuum oven under pressure of 100 mmHg and at temperature of 95°C for 5 hours. Thereafter, the dish was covered with a lid and transferred to a desiccator to cool. After cooling, the lid cover was removed and the dish together with the dried sample was weighed as W_3. The moisture content and dry matter were respectively determined as follow:

$$Moisture\ (\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$ ---------- Eq. 8

Where;
- ➢ W_1 is the mass of aluminium dish without lid,
- ➢ W_2 is mass of sample plus aluminium dish before drying, and
- ➢ W_3, is the mass of sample plus aluminium dish after drying

Dry matter (%) = 100 – moisture (%)

2.3.8 Available carbohydrate content

The available carbohydrate content (%) was calculated by subtracting the sum percentage of moisture, protein, fat, ash, crude fibre (Rand et al, 1991; FAO, 2003), using the formula:

Available carbohydrate content (%) = 100 – (moisture% + CP% + fat% + ash% + CF%) --- Eq. 9

Where CP = crude protein, and CF = crude fibre.

2.3.9 Acid Detergent Fibre (ADF)

The ADF of the fodder samples was determined by boiling the sample in an acid detergent solution (Rusche, 2019). Each of the samples was first incubated with pepsin under acid conditions for 24 hours, then extracted with acid detergent solution and the remaining residue was dried and ashed. The pepsin – acid solution was prepared by dissolving 4g of pepsin in 0.075M hydrochloric acid previously heated to 45ºC (Goering & Van Soest, 1970).

A measured amount, 1g of the ground and sieved (< 1 mm sieve) sample was transferred into a large glass test tube and the mass was weighed as W_1. Then, 50cm^3 of pepsin – acid solution (1:10000) heated at 45ºC was added. The sample was completely dispersed and then placed in a water bath at 45ºC. The sample was then mixed intermittently by swirling and incubated in the water bath for 24 hours.

Then, the incubated sample solution was transferred into crucible, and filtered by suction while rinsing with warm water at 50 ºC. The crucible with sample residues was placed in the extraction unit for heating and 100cm^3 of cold acid detergent solution was added. The solution was heated to boil, then the heat was adjusted to 75ºC and the solution was heated at this temperature for 60 minutes (Goering & Van Soest, 1970).

Thereafter, the solution was filtered out by suction, washed 3 times with warm water at 50 ºC and rinsed twice with acetone after which it was allowed to soak for 2 minutes. Then, the sample was dried overnight at 105 ºC and cooled in a desiccator for 30

minutes, and the mass was weighed as W_2, the mass of the residue in crucible after drying was obtained. The sample solution was ashed for 4 hours at 500 ºC, then the furnace was allowed to cool to below 250 ºC and the crucible was removed and placed in desiccator for 30 minutes. The crucible was weighed to obtain the mass of residue in crucible after ashing as W_3 (Rusche, 2019). The ADF% was calculated as follow;

$$ADF\ (\%) = \frac{(W_2) - (W_3)}{W_1} \times 100$$ ---------- Eq. 10

Where:
- ➢ W_1 = Mass of original sample, in g
- ➢ W_2 = Mass of residue after drying, in g
- ➢ W_3 = Mass of residue after ashing, in g

2.3.10 Neutral Detergent Fibre (NDF)

For each sample, a measured amount, 1g of the ground and sieved (< 1 mm sieve) sample was transferred into a sintered glass crucible and the combined mass of the crucible plus the content was weighed and recorded as W_1. The crucible together with the content was placed on the extraction unit and 50cm^3 of cold neutral detergent solution (NDS) was added (Rusche, 2019). The solution was then brought to boiling point for 30 minutes after which 2cm^3 of alpha – amylase solution was added (AOAC, 1995). Then, another 50cm^3 of cold NDS was added and again brought to boil (Rusche, 2019).

The extraction was terminated after 60 minutes of boiling, and the NDS was filtered out by suction, washed with hot water (at 95 ºC) and soaked in this hot water for 2 minutes, then filtered by vacuum. The washing was repeated until all traces of foam have disappeared, and the sample was then washed thrice with acetone. Thereafter, it was dried overnight at 105ºC, cooled in a desiccator for 30 minutes and weighed to obtain second mass of the sample (W_2). Then, the sample was ashed for 4 hours at 500ºC and the crucible was removed and placed in a desiccator (Rusche, 2019). The crucible was allowed to cool then weighed again to obtain the third mass of the sample (W_3). Thereafter, the NDF% was calculated as follow:

$$NDF\ (\%) = \frac{W_2 - W_3}{W_1} \times 100$$ ---------- Eq. 11

Where:
- ➢ $W1$ = Mass of the sample, in g
- ➢ $W2$ = Residue in crucible after drying, in g
- ➢ $W3$ = Residue in crucible after ashing, in g

2.3.11 Acid Detergent Lignin (ADL)

The procedure for the sample preparation was similar to the procedure used in sample preparation for the determination of ADF above. After extraction, each sample's dried residue was placed in a crucible and the combined mass was weighed as W_1 (Goering & Van Soest, 1970). To each crucible, 5cm^3 of 72% H_2SO_4 solution was added and a glass rod was used to carefully mix the sample (Rusche, 2019). Then, 20cm^3 of the 72% H_2SO_4 solution was added with warmth at 20 ºC and stirred carefully.

The extraction was carried out at room temperature for 3 hours, while stirring the sample carefully after every 30 minutes (Rusche, 2019). The crucible was then placed on vacuum suction, filtered and washed 3 times with warm water at 50ºC (Goering, & Van Soest, 1970) and dried overnight in an oven at 105 ºC. The sample was cooled for 30 minutes in a desiccator and second sample mass (W_2) was weighed. The crucible was then placed in furnace and ashed at 500 ºC for 4 hours (Goering & Van Soest, 1970). Before removing the crucible, the furnace was cooled to below 250 ºC and the crucible was removed and cooled further inside desiccator for 30 minutes and weighed again (W_3). Thereafter, the ADL% was calculated as follow;

$$ADL\ (\%) = \frac{W_2 - W_3}{W_1} \times 100$$ ---------- Eq. 12

Where:

- W_1 = Mass of the sample, in g
- W_2 = Mass of residue after drying, in g
- W_3 = Mass of residue after ashing, in g

2.3.12 Data analysis

The Statistical Package for Social Science (SPSS Statistics 20) was used to capture and perform the data analyses of the chemical compositions of the grain and fodder samples crops. Five replicate data of the chemical compositions of each crop was computed as mean. Then, T – test ($p < 0.05$) was used to determine the significance of data variation between the chemical compositions of each crop harvested in the two experimental farms (Otuzemba and Swartbooisdrift). T – test analysis has been widely used to estimate the statistical differences between two groups (Bevans, 2020).

3. Results and Discussion

3.1 Nutritional values of the grains

Figure 1 shows the grains' mean proximate compositions (n = 5) recorded at Otuzemba and Swartbooisdrift experimental farms respectively during the study. The following parameters were assessed: moisture content, total ash, crude protein, fat content, crude fibre, carbohydrates, phosphorus, and calcium.

3.2 Moisture (%)

Results of the moisture content (%) of the grains harvested after complete maturity at the Otuzemba experimental farm showed that all the harvested grain crops recorded moisture content of less than 10%, ranging from 4.6% to 9.5% (Figure 1). The present results revealed that maize

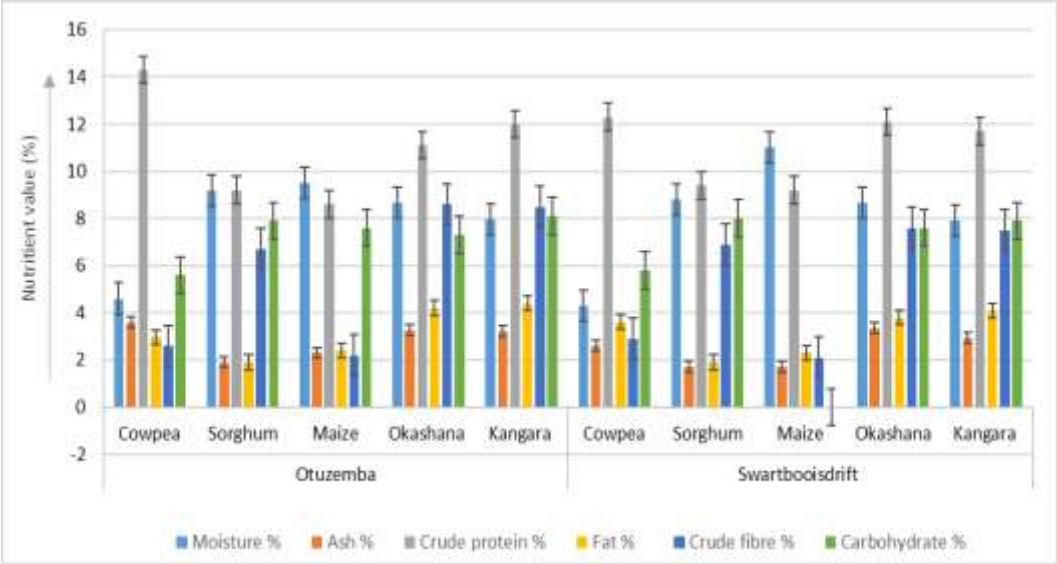

Figure 1: Proximate compositions of the grains harvested at at Otuzemba and Swartbooisdrift experimental farms (n = 5); *Okashana and Kangara are pearl millet varieties*

crop recorded the highest moisture content of 9.5% while cowpea recorded the lowest moisture content of 4.6%. The results further show that sorghum recorded 9.2%, okashana and kangara (pearl millet) recorded 8.65% and 7.95% respectively. At the Swartbooisdrift experimental farm, the grains' moisture contents were generally less than 12%. Maize grains still recorded the highest moisture content of 11% while cowpea grains recorded the lowest moisture content of 4.3%. Sorghum grains recorded 8.8%, okashana grains 8.68% and kangara grains 7.93% moisture content. The result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the moisture content

recorded in the grains at both Otuzemba and Swartbooisdrift experimental farms was not significant ($p = 0.33$).

Generally, the recorded moisture levels of the grains correspond to the acceptable moisture level of less than 12% for good grain quality (Christensen & Kaufmann, 1965). According to Likhayo, et al, *(*2018), grain moisture content should be reduced to low levels (less than 12%) to attain high quality grain as low moisture content minimizes insect infestation. Post-harvest losses of food grains, caused by insect infestation and mold activity, have been conservatively estimated at 10–15% (Weinberg, 2008). Under dry conditions, grains can be stored for extended periods provided that there is no insect infestation or microbial activity (Weinberg et al., 2008). Under humid storage conditions however, grains may deteriorate rapidly resulting in both qualitative and quantitative losses, and such deterioration is accelerated at higher temperatures (Weinberg et al., 2008). Lacey et al. (1980) noted that some of these quality losses are difficult to detect visually. Thus, from both economic and feed quality viewpoints, the low moisture content of the harvested grains in the present study is a good sign for the feed grain quality.

3.3 Total Ash (%)

The total ash content of the harvested grains at Otuzemba experimental farm (Figure 1) ranges from 1.9% to 3.6% which is within the acceptable threshold levels of 1.2% to 5.4% (Ki, *et al,* 2017; Saleh, *et al*, 2013; Nuss & Tanumihardjo, 2010; Dicko, 2006). Cowpea recorded the highest ash content of 3.6%, while sorghum recording the lowest ash content of 1.9%. The results further showed that maize recorded 2.3%, Okashana 3.25%, and Kangara 3.21% ash contents. At the Swartbooisdrift experimental farm, the ash contents of the grains ranged from 1.7% to 3.35%. Okashana recorded the highest ash content of 3.35%, while sorghum and maize recorded the lowest ash content of 1.7% each. Kangara recorded 2.92% and cowpea recorded 2.6% ash content. These values also fall within the above reported acceptable threshold levels. The result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the total ash content recorded for the crops at both Otuzemba and Swartbooisdrift experimental farms was not significant ($p = 0.05$).

It has been reported that if the ash content of a feed is abnormally high, there is a very good chance that the feed is contaminated with soil which is not desirable (Hoffman, 2005). According to Ki *et al.* (2017), the functionality of the mineral content of grain crops hugely depend on ash levels. Crude ash plays an important role in the nutritional interpretation of feeds by allowing indirect estimation of total organic matter, which encompasses all potential energy-producing compounds (Souza et al., 2017). Crude ash estimates have been incorporated as an important input into summative systems for the estimation of energy contents in animal diets (NRC, 2021; Valadares et al., 2016; Tedeschi et al., 2005). Thiex (2012) added that any bias in crude ash estimates might decrease the accuracy of the nutritional evaluation of animal feeds, which in turn may compromise production and culminate in economic losses due to inadequate diet formulation. The recorded threshold levels of the ash content in the harvested grain crops at both experimental farms implies good mineral elements availability in the grains, and are thus, suitable feed for both humans and animal nutrition.

3.4 Crude protein

Results of crude protein content of the grains at Otuzemba experimental farm (Figure 1) ranged from 8.6% to 14.3% whereby, cowpea recorded the highest crude protein of 14.3% and maize recording the least (8.6%). Sorghum grain recorded crude protein of 9.2%, Okashana recorded 11.1%, and Kangara recoded 12.0%. At Swartbooisdrift experimental farm, the grains' crude protein contents ranged from 9.2% to 12.3%. Cowpea also recorded the highest crude protein content of 12.3% while maize recorded the least, 9.2%. The other results showed that sorghum recorded 9.4%, Okashana recorded 12.1%, and Kangara recoded 11.7%. The result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the crude protein content recorded for the crops at both Otuzemba and Swartbooisdrift experimental farms was also not significant ($p = 0.42$).

Interesting, the crude protein contents of all the grains fall within the standard values of 7% to 15% for cereal grain's protein content (Sade, 2009; Dicko, 2006). These indicate sufficient protein levels which is essential for both human and livestock nutrition. According to Xia et al. (2018),

dietary crude protein is crucial for promoting ruminal fermentation and nutrient digestibility. Nutrient intake and apparent digestibility increase with an increase in dietary CP level (Kang et al., 2015). Moreover, protein supplementation of low-quality coarse diet may improve roughage utilization and productive performance of cattle (Detmann et al., 2011). Ruminal fermentation can be improved because cattle receiving diets containing high CP level show significantly higher bacterial population (Kang et al., 2015), microbial protein synthesis (Norrapoke et al., 2012) and volatile fatty acid (VFA) concentration in rumen fluid (Abadi et al., 2015; Hatfield et al., 1998). than cattle receiving diets containing low CP level (Xia et al., 2018). In an online blog, Brf Ingredient (2022) noted that because protein is a crucial component in feed production, zootechnicians or animal feed formulators (or both) look for ingredients with high protein content and an appropriate balance of amino acids at lower costs. Thus, exploring and expanding irrigation-fed grain feeds production, especially in the study area could reduce the economic impact of sourcing additional protein feed through supplementary feeding as the harvested grain protein contents recorded at both experimental farms are within acceptable levels.

3.5 Fat content

The harvested grains at Otuzemba experimental farm recorded fat contents ranging from 1.9% to 4.4% (Figure 1). The two pearl millet varieties: Kangara and Okasana recorded higher fat contents of 4.4% and 4.2% respectively. The fat contents of the other crops' grains are 1.9% sorghum, 2.96% cowpea, and 2.4% maize. At the Swartbooisdrift experimental farm, the recorded grain fat content ranges from 1.9% to 4.1%; with cowpea recording 3.6%, sorghum 1.9%, Okashana 3.8%, Kangara 4.1% and maize 2.3%. These values are also within the standard grain food fat content of 1.5% to 5.6% (Sade, 2009; Kulamarva *et al*, 2009; Malik, 2015; Jayathilake, *et al.* 2018). The result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the fat content recorded for the grains at both Otuzemba and Swartbooisdrift experimental farms was also not significant ($p = 0.43$).

Fat contents of feeds play an important role in improving the absorption of fat soluble vitamins and reducing the powderiness of feeds (Çetingül & Yardimci, 2008). According to Çetingül and Yardimci, (2008), the diet of farm animals has been traditionally low in fat, especially in herbivores; not more than 2- 5% of digestible energy. Hence, fat supplements have been used to enhance productive performance in cattle, pigs and poultry, and there is currently much interest in optimizing the amount and type of fat in the diets of farm animals (Çetingül & Yardimci, 2008). According to Kerr et al. (2015), lipids are a concentrated energy source, and inclusion of lipids are known to affect growth rate and feed efficiency, improve diet palatability, feed dustiness, and pellet quality. Thus, the recorded fat levels in the harvested grains imply sufficient stored energy for quality feed and animal nutrition.

3.6 Crude fibre

The crude fibre (CF) results of the harvested grains at Otuzemba experimental farm range from 2.2% to 8.6% (Figure 1). Okashana grains recorded the highest CF of 8.6%, followed by Kangara garins 8.5%, sorghum grains 6.7%, cowpea grains 2.6%, and maize grains recorded the least, 2.2%. Similar results at the Swartbooisdrift experimental farm showed that Okashana grains recorded CF of 7.8%, Kangara garins 7.5%, sorghum grains 6.9%, cowpea grains 2.9%, and maize grains 2.1%. The results showed that the crude fibre levels of maize and cowpea grains fall within the standard value of 1.4% to 3.7% (Gomez, 2004; Inobeme, 2014), while values recorded by sorghum, Okashana and Kangara are slightly higher than the standard values.

Generally, the result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the CF content recorded in the grains at both Otuzemba and Swartbooisdrift experimental farms was also not significant ($p = 0.16$). Crude fibre determines the indigestible carbohydrates in human and animal feed (Likhayo, *et al*, 2018). It is the measure of indigestible cellulose and other lignin in feed. According to Dobos et al. (2019), feed with higher crude fiber remains longer in the stomach and increasing the sensation of satiety, noting that this effect is utilized in several areas of feeding. For example, during fattening pigs, feed with higher fiber content reduces the lipidosis of rearing pigs (Dobos et al., 2019).

3.7 Carbohydrates

The grains' carbohydrate levels recorded at the Otuzemba experimental farm range from 56% to

81%, with Kangara and cowpea recording the highest and lowest levels respectively. The other results revealed that sorghum recorded carbohydrate content of 79%, Maize 76%, and Okashana 73% (Figure 1). Apart from Kangara and cowpea grains (at Otuzemba experimental farm) and sorghum and cowpea grains (at Swartbooisdrift experimental farm), all the other grains' carbohydrate contents fall within the standard values of 63% – 79% for a grain carbohydrate content (Saleh *et al.*, 2013; Dicko (2006). Similar results at the Swartbooisdrift experimental farm revealed that cowpea still recorded the lowest carbohydrate level (58%) but sorghum recorded the highest level (80%). In the other results, maize recorded 72.8%, Okashana 76% and Kangara 79%. The result of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of the grains' carbohydrate contents recorded at both Otuzemba and Swartbooisdrift experimental farms was not statistically significant ($p = 0.45$).

Carbohydrates are the main source of energy for the regular functioning of the body and grains have been recognized an important source of carbohydrates in human and livestock feeds (Pathak, 2020). According to Clemente-Suárez et al. (2022), foods high in carbohydrates are an important part of a healthy diet, since they provide the body with glucose to support bodily functions and physical activity. In a study titled: Carbohydrates effects on nutrition and health functions in pigs, Zhou et al. (2021) noted that besides its primary energy source, different types and structures of carbohydrates are a benefit for nutrition and health functions in pigs, which are involved in promoting growth performance and intestinal functions, regulating the community of gut microbiota, and modulating the lipids and glucose metabolism. However, the sources of dietary carbohydrate are an essential factor likely associated with the clinical and physiological effects that can promote or impair health (Zhou et al., 2021). Thus, the high levels of carbohydrates recorded in the grains in this study mean that they could provide a cheap sources of carbohydrates in human and livestock feeds, especially in the supplementation of low carbohydrate diets.

3.8 Mineral elements (phosphorus and calcium)

Figure 2 shows the results of the mean levels (n = 5) of the mineral elements (phosphorus and calcium) in the grains harvested at Otuzemba and Swartbooisdrift experimental farm during the

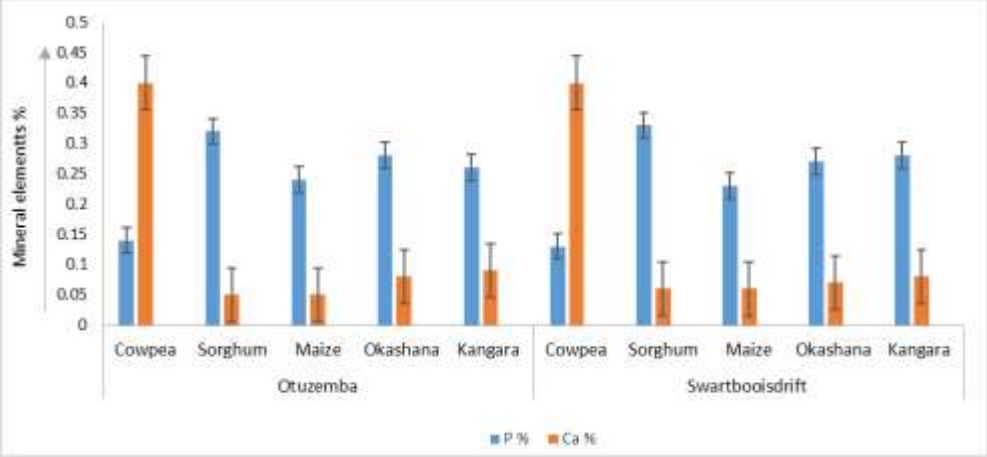

Figure 2: Mineral element compositions of the grains harvested at the two experimental sites

Key: Ca % x 10 in Okashana and Kangara

study. At the Otuzemba experimental farm, the results revealed that grains' phosphorus ranged from 0.14% to 0.32%, and calcium ranged from 0.008% to 0.4%. Sorghum recorded phosphorus content of 0.32%, and calcium 0.05%; maize recorded phosphorus content of 0.24%, and calcium 0.05%; Okashana recorded phosphorus content of 0.28%, and calcium 0.008%; while Kangara recorded phosphorus content of 0.26%, and calcium 0.009%.

Cowpea grains recorded the lowest phosphorus levels of 0.14% although, it is within the standard

values of 0.01% to 0.368% for grain phosphorus (Jayathilake, *et al,* 2018). The cowpea grains' mean calcium levels (0.4%) is slightly higher than the standard values of 0.021% to 0.38% for grain calcium (Inobeme, 2014).

At the Swartbooisdrift experimental farm, similar results of phosphorus and calcium in the grains were 0.13% to 0.33% phosphorus, and 0.007% to 0.4% calcium (Figure 2). Cowpea recorded phosphorus content of 0.13%, and calcium 0.4%; sorghum recorded phosphorus content of 0.33%, and calcium 0.06%; maize recorded phosphorus content of 0.23%, and calcium 0.06%; Okashana recorded phosphorus content of 0.28%, and calcium 0.007%; while Kangara recorded phosphorus content of 0.28%, and calcium 0.008%.

The results of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of these mineral elements (P and Ca) recorded in the grains at both Otuzemba and Swartbooisdrift experimental farms were also not significant ($p = 0.5$ and 0.12 respectively). The phosphorus levels of the sorghum grains fall within the acceptable standard values while maize, Okashana and Kangara grains recorded slightly low phosphorus contents. The results further indicate that sorghum and maize grains contain sufficient calcium while Okashana and Kangara recorded low calcium content at the Swartbooisdrift experimental farm. According to Upadhaya and Kim (2020), mineral elements are inorganic nutrients that are required in small quantities by the body but participate in orchestration of different biological processes that drive normal growth, development and function. It is well-established that the deficiency or inadequate amount of these minerals in the diet may impair productivity, immune functions and health (Radwinska & Zarczynska, 2014; Wu et al., 2019). Apart from Okashana and Kangara (pearl millet varieties) which recorded low levels of calcium and phosphorus, the other grains (maize, cowpea and sorghum) recorded optimum levels of the minerals (Ca and P) determined in the present study and hence, could provide nutritive human and animal nutrition.

3.9 Chemical compositions of the fodders of cowpea, sorghum, maize, pearl millet (Okashana and Kangara)

Figures 3 shows some of nutritional compositions of fodders harvested at the two experimental sites. The fodders consist of plant straw and leaves harvested from cowpea, sorghum, maize, and pearl millet (Okashana and Kangara) cultivated under irrigation-fed farming. At the Otuzemba

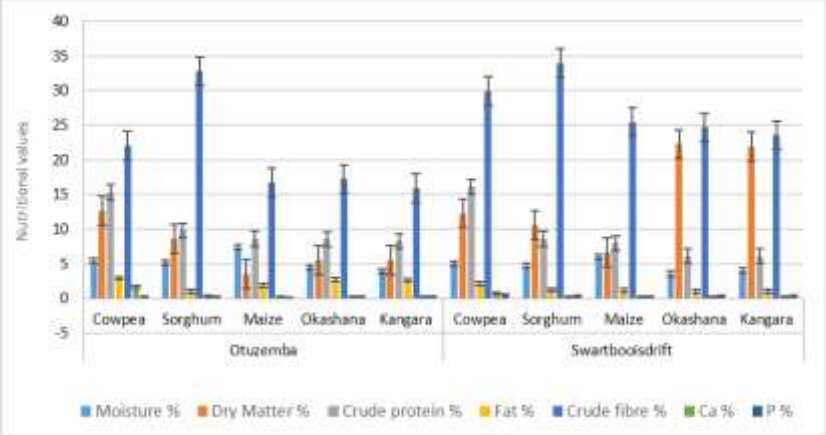

Figure 3: Nutritional compositions of the fodders harvested at the two experimental sites

experimental farm, the results revealed that cowpea fodder recorded moisture content of 5.43%, dry mater of 12.60%, crude protein of 15.33%, fat content of 2.94%, crude fibre content of 22.02%, calcium level of 1.64%, and phosphorus level of 0.27%. Similar results at the Swartbooisdrift experimental farm showed that cowpea fodder recorded moisture content of 5.02%, dry mater of 12.30%, crude protein of 16.11%, fat content of 2.15%, crude fibre of 29.91%, calcium level of 0.77% and phosphorus level of 0.54%.

At the Otuzemba experimental farm, sorghum fodder recorded moisture content of 5.18%, dry mater of 8.60%, crude protein of 9.81%, crude fibre of 32.79%, and fat content of 0.99%, while calcium

and phosphorus contents were 0.33% and 0.31 respectively. Similar results at the Swartbooisdrift experimental farm were 4.72% moisture content, 10.60% dry mater, 8.55% crude protein, 1.23% fat content, 33.94% crude fibre, 0.21% calcium, and 0.37% phosphorus in the sorghum fodder.

Maize fodder at the Otuzemba experimental farm recorded 7.34% moisture content, 8.60% dry mater, 8.59% crude protein, 0.99% fat content, 16.71% crude fibre, 0.19% Ca and 0.20% P, while at the Swartbooisdrift experimental farm, the results were 6.04% moisture content, 6.60% dry mater, 7.98% crude protein, 1.15% fat content, 25.45% crude fibre, while Ca P were 0.23% and 0.26% respectively.

At the Otuzemba experimental farm, Okashana fodder recorded moisture content of 4.46%, dry mater of 5.52%, crude protein of 8.52%, fat content of 2.72%, crude fibre of 17.23%, while calcium and phosphorus contents were 0.13% and 0.30% respectively. Similar results at the Swartbooisdrift experimental farm were 3.54% moisture content, 22.26% dry mater, 6.13% crude protein, 1.05% fat content, 24.06% crude fibre, 0.17% Ca, and 0.36% P.

At the Otuzemba experimental farm, Kangara fodder recorded moisture content of 3.92%, dry mater of 5.46%, crude protein of 8.26%, fat content of 2.60%, crude fibre of 15.89%, calcium 0.14%, and phosphorus 0.31%. Similar results at the Swartbooisdrift experimental farm were 4.01% moisture content, 21.95% dry mater, 6.11% crude protein, 1.02% fat content, 23.56% crude fibre, while calcium and phosphorus 0.12% and 0.41% respectively in the Kangara fodder.

Generally, the results of the different nutrient compositions analyzed in the fodder samples fall within their recommended standard values for animal feeds (Saleh *et al*, 2013).

Figure 4 depicts the results of acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL) determined in the crop fodders at the two experimental sites. At the Otuzemba experimental farm, cowpea fodder recorded ADF of 35.81%, NDF of 47.06%, and ADL of 6.08% while similar results were 26.93% ADF, 35.63% NDF, and 5.07% ADL at the Swartbooisdrift experimental farm.

Sorghum fodder recorded ADF of 36.90%, NDF of 68.92%, and ADL of 4.35% at the Otuzemba experimental farm while at the Swartbooisdrift experimental farm, the results were 37.06% ADF, 65.63% NDF, and 4.69% ADL.

The results of ADF, NDF, and ADL in the maize fodder were 21.18%, 49.20%, and 2.75 respectively at the Otuzemba experimental farm while the results were 29.43% ADF, 62.16% NDF, and 3.20% ADL at the Swartbooisdrift experimental farm.

Okashana recorded 20.95% ADF, 38.46% NDF, and 4.28 ADL at the Otuzemba experimental farm while similar results at the Swartbooisdrift experimental farm were 28.14% ADF, 48.10% NDF, and 4.10% ADL.

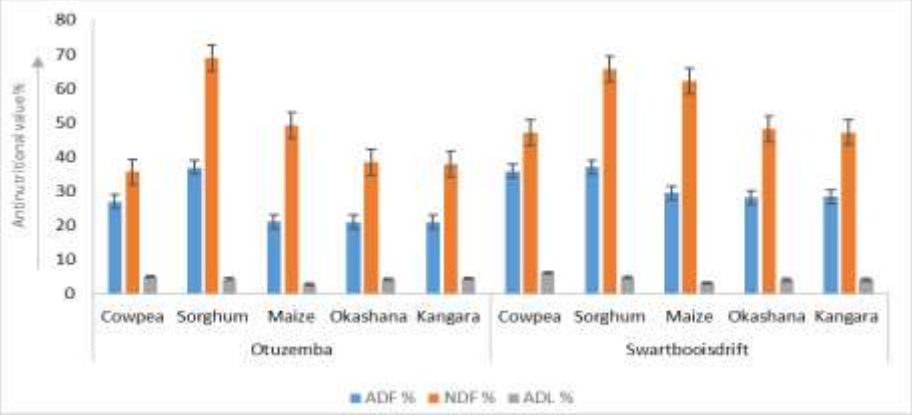

Figure 4: Acid detergent fibre, neutral detergent fibre, acid detergent lignin mean values (n = 5) of the fodders harvested at the two experimental sites

At the Otuzemba experimental farm, Kangara fodder recorded 21.03% ADF, 37.98% NDF, and 4.38% ADL while similar results at the Swartbooisdrift experimental farm were 47.20% ADF, 28.43% NDF, and 4.10% ADL (Figure 4).

The results of ADF, NDF, and ADL recorded in the fodders fall within their reported standard values of ADF < 30%, NDF < 50%, and ADL2% – 8% (Iqbal & Iqbal, 2015; Tamta *et al*, 2019; Carcea, 2020). The results of t-Test analysis (at $p < 0.05$) of the variation between paired sample means of ADF and NDF contents recorded in the fodders at both Otuzemba and Swartbooisdrift experimental farms differed significantly ($p = 0.01$ and 0.02) between the study location while ADL was not significant ($p = 0.16$). Both ADF and NDF in crops have been shown to vary under drought stress conditions (Kuchenmeister et al., 2013; Peterson et al., 1992), and drought stress is a typical feature of the study area. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations are important quality parameters of forages (Schroeder, 1994; Caballero et al., 1995; Henning et al., 1996; Assefa and Ledin, 2001; Albayrak et al., 2011). There is inverse relation between ADF percent of a forage and its dry matter value, likewise; similar relation has been established between NDF percent of a forage and its dry matter intake value (Sayar et al., 2014). Notably, as ADF percent of a forage increase, its dry matter digestibility by livestock decreases, similarly, as NDF percent of a forage increases, intake amount of the forage by livestock decreases (Lacefield, 1988; Schroder, 1994; Henning et al 1996; Jeranyama & Garcia, 2004; Sayar et al., 2014). However, both ADF and NDF levels recorded in this study are within acceptable limits and hence, suggest that the fodders of cowpea, sorghum, maize, Okashana, and Kangara cultivated using the irrigation-fed farming are suitable for livestock nutrition.

4. Conclusion

This study assessed the nutritional compositions of grains and fodders of selected crops (maize, sorghum, cowpea and pearl millet (Kangara and Okashana) cultivated under experimental irrigation-fed farming at Otuzemba and Swartbooisdrift in the Kunene Region of Namibia. The results of the study revealed that apart from Okashana and Kangara (pearl millet varieties) grains which recorded low levels of calcium and phosphorus, the rest of the grains and fodders recorded adequate levels of moisture, ash content, crude protein, fat content, crude fibre, carbohydrate content, phosphorus, calcium, and potassium. Additionally, the levels of dry matter, acid detergent fibre, neutral detergent fibre, and acid detergent lignin determined in the fodders fall within the acceptable range for quality livestock feeds. Generally, the research findings are indicative of the prospect of producing quality grains and fodders from cowpea, sorghum, maize, Okashana, and Kangara using irrigation – fed farm in the study area. Since all these crops could produce edible grains and fodders for human and livestock nutrition, developing the irrigation-fed farming to expand the cultivation of these crops could become a major step towards promoting agriculture and hence, improving food security in the Kunene Region of Namibia.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

1. Abadi, E.I.K.,, Tahmasebi, A., Mesgaran, M.D., Naserian, A.A., & Vakili, A. (2015). Effect of dietary crude protein level on UT-B expression and nitrogen efficiency in growing Baluchi male lambs fed low or high concentrate diets. Iranian Journal of Applied Animal Science, 5(2), 323-332.
2. Abadi, M.K., Subramanian, R., Kia, S. M., Avesani, P., Patras, I., & Sebe, N. (2015). DECAF: MEG-based multimodal database for decoding affective physiological responses. IEEE Transactions on Affective Computing, 6(3), 209-222.
3. Abdulrazak, S. A., Fujihara, T., Ondiek, J. K., & Ørskov, E. R. (2000). Nutritive evaluation of some Acacia tree leaves from Kenya. Animal feed science and technology, 85(1-2), 89-

98.Albayrak, S., Mevlüt, T. Ü. R. K., YUeKSEL, O., & Yilmaz, M. (2011). Forage yield and the quality of perennial legume-grass mixtures under rainfed conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 39(1), 114-118.

4. Amole, T.A., Panyan, E., Adekeye, A., Ayantunde, A., Duncan, A., & Blummel, M. (2021). Productivity nutritive value and economic potential of irrigated fodder in two regions of Ghana, Agronomy Journal, 114, 148–164, DOI: 10.1002/agj2.20884
5. Arya, S.L., Panwar, P., & Yadav, R.P. (2011). Role of watershed management in bridging demand–Supply gap of fodder for enhancing livestock production in Shivaliks. Haryana Agricultural Economics Research Review, 24, 225– 233.
6. Association of Official Analytical Chemists - AOAC. (1995). Official methods of analysis of AOAC International. Assefa, G., & Ledin, I. (2001). Effect of variety, soil type and fertiliser on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. Animal feed science and technology, 92(1-2), 95-111.
7. Bationo, A., Kihara, J., Vanlauwe, B., Waswa, B., & Kimetu, J. (2007). Soil organic carbon dynamics, functions and management in West African agro-ecosystems. Agricultural systems, 94(1), 13-25.
8. Caballero, R., Goicoechea, E. L., & Hernaiz, P. J. (1995). Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field crops research, 41(2), 135-140.
9. Carcea, M. (2020). Nutritional value of grain-based foods. Foods, 9(4), 504. Çetingül, İ. S., & Yardımcı, M. (2008). The importance of fats in farm animal nutrition. Kocatepe Veterinary Journal, 1(1).
10. Census, NSA. (2011). Namibia 2011 population and housing – census indicators. https://nsa.nsa.org.na/new_publications/namibia-2011-population-and-housing-census-indicators/
11. Chakravarti, L. J., Beltran, V. H., & van Oppen, M. J. (2017). Rapid thermal adaptation in photosymbionts of reef- building corals. Global change biology, 23(11), 4675-4688.
12. Christensen, C. M., & Kaufmann, H. H. (1965). Deterioration of stored grains by fungi. Annual Review of Phytopathology, 3(1), 69-84.
13. Clemente-Suárez, V., Mielgo-Ayuso, J., Martín-Rodríguez, A., Ramos-Campo, D., Redondo- Flórez, L., & Tornero-Aguilera, J. F. (2022). The Burden of Carbohydrates in Health and Disease. Nutrients 2022, 14, 3809.
14. Coleman, S. W., & Moore, J. E. (2003). Feed quality and animal performance. Field Crops Research, 84(1-2), 17-29.
15. Committee on Animal Nutrition - NRC. (2001). Nutrient requirements of dairy cattle. National Academy Press. Detmann, E., Queiroz, A. C. D., Zorzi, K., Mantovani, H. C., Bayão, G. F. V., & Gomes, M. P. C. (2011). In vitro degradation of neutral detergent fiber of low-quality tropical forage according to supplementation with true protein and (or) non-protein nitrogen. Revista Brasileira de Zootecnia, 40, 1272-1279.
16. Devendra, C., & Thomas, D. (2002). Crop–animal interactions in mixed farming systems in Asia. Agricultural Systems, 71(1-2), 27-40.
17. Dicko, M. H., Gruppen, H., Traoré, A. S., Voragen, A. G., & Van Berkel, W. J. (2006). Sorghum grain as human food in Africa: relevance of content of starch and amylase activities. African journal of biotechnology, 5(5), 384-395.
18. Dobos, A., Bársony, P., Posta, J., & Babinszky, L. (2019). Effect of feeds with different crude fiber content on the performance of meat goose, Acta Agraria Debreceniensis, 2, 5 – 8, DOI: 10.34101/actaagrar/2/3670
19. Ferreira, L., Sanches, A., Mendonça, F., Gomes, P., Pezzopane, M., Couto, R., Biconi-Pacheco, A., Lisboa, C. & Gomes, R. (2020). Yield parameters and water productivity of tropical and overseeded winter forages. International Journal for Innovation Education and Research, 8, 760– 774.
20. Food and Agriculture Organisation of the United Nations [FAO] (2003). Food energy - methods of analysis and conversion factors, Report of a technical workshop, Rome, 3-6 December 2002, FAO Food and Nutrition Paper 77.
21. Geng, Y., Ranjitkar, S., Yan, Q., He, Z., Su, B., Gao, S., ... & Xu, J. (2020). Nutrient value of wild fodder species and the implications for

improving the diet of mithun (Bos frontalis) in Dulongjiang area, Yunnan Province, China. Plant Diversity, 42(6), 455-463.

22. Getnet, K., Haileslasseie, A., Dessalegne, Y., Hagos, F., Gebrehaweria, G., & Gebremedhin, B. (2016). On the profitability of irrigated fodder production: comparative evidence from smallholders in Koga irrigation scheme, Ethiopia. Animal Production Science, 57(9), 1962-1974.
23. Gomez Carlos, P. (2004). Cowpea Post-Harvest Operations. Food and Agriculture Organization of the United Nations, 1-70.
24. Hatfield, P. G., Hopkins, J. A., Ramsey, W. S., & Gilmore, A. (1998). Effects of level of protein and type of molasses on digesta kinetics and blood metabolites in sheep. Small Ruminant Research, 28(2), 161-170.
25. Henning, J. C., Lacefield, G. D., & Amaral-Phillips, D. (1996). Interpreting forage quality reports. Agron. Publ. ID-101., University of Kentucky, Lexington, KY. Hoffman, A. J. (2005). Climate change strategy: The business logic behind voluntary greenhouse gas reductions. California Management Review, 47(3), 21-46.
26. Ibrahimi K. A. E., Tahmasebi, A. M., Danesh Mesgaran, M., Naserian, A. A., & Vakili, (2015). Effect of dietary crude protein level on UT-B expression and nitrogen efficiency in growing Baluchi male lambs fed low or high concentrate diets. Iranian Journal of Applied Animal Science, 5(2), 323-332.
27. Inobeme, A., Nlemadim, A. B., Obigwa, P. A., Ikechukwu, G., & Ajai, A. I. (2014).
28. Determination of proximate and mineral compositions of white cowpea beans (Vigna unguiculata) collected from markets in Minna, Nigeria. International Journal of Scientific and Engineering Research, 5, 502-504.
29. Jadalla, A., Page, M., Ginex, P., Coleman, M., Vrabel, M., & Bevans, M. (2020). Family Caregiver Strain and Burden: A systematic review of evidence-based interventions when caring for patients with cancer. Clinical Journal of Oncology Nursing, 24(1).
30. Jeranyama, P., & Garcia, A. D. (2004). Understanding relative feed value (RFV) and relative forage quality (RFQ).
31. Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., & Liyanage, R. (2018). Cowpea: an overview on its nutritional facts and health benefits. Journal of the Science of Food and Agriculture, 98(13), 4793-4806
32. Kang, S., Wanapat, M., Phesatcha, K., & Norrapoke, T. (2015). Effect of protein level and urea in concentrate mixture on feed intake and rumen fermentation in swamp buffaloes fed rice straw-based diet. Tropical Animal Health and Production, 47, 671-679.
33. Karunanayaka, S. P., & Naidu, S. (2013). Capacity building of academic staff in the integration of ICT and OER in teacher education programs at the Open University of Sri Lanka. Kerr, B. J., Kellner, T. A., & Shurson, G. C. (2015). Characteristics of lipids and their feeding value in swine diets. Journal of Animal Science and Biotechnology, 6(1), 1-23.
34. Ki, K. S., Park, S. B., Lim, D. H., & Seo, S. (2017). Evaluation of the nutritional value of locally roduced forage in Korea using chemical analysis and in vitro ruminal fermentation. Asian-Australasian journal of animal sciences, 30(3), 355.
35. Küchenmeister, K., Küchenmeister, F., Kayser, M., Wrage-Mönnig, N. & Isselstein, J. (2013). Influence of drought stress on nutritive value of perennial forage legumes. International Journal of Plant Production. 7, 1735-6814.
36. Kulamarva, A. G., Sosle, V. R., & Raghavan, G. V. (2009). Nutritional and rheological properties of sorghum. International Journal of Food Properties, 12(1), 55-69.
37. Lacey, R. E. (1980). Energy by reverse electrodialysis. Ocean engineering, 7(1), 1-47.Lacefield, G. D. (1988). Alfalfa hay quality makes the difference.Le Houérou, H. N. (1980). Chemical composition and nutritive value of browse in tropical West Africa. Browse in Africa, 261-289.
38. Likhayo, P., Bruce, A. Y., Tefera, T., & Mueke, J. (2018). Maize grain stored in hermetic bags: Effect of moisture and pest infestation on grain quality. Journal of Food Quality.Lounglawan, P., Lounglawan, W., & Suksombat, W. (2014). Effect of cutting interval and cuttingheight on yield and chemical composition of King Napier grass (Pennisetum purpureum x Pennisetum americanum). APCBEE procedia, 8, 27-31.Mæhre, H. K., Dalheim, L., Edvinsen, G. K., Elvevoll, E. O., & Jensen, I. J. (2018).

39. Protein determination—method matters. Foods, 7(1), 5. Malik, S. (2015). Pearl millet-nutritional value and medicinal uses. Int. J. Adv. Res. Innov. Ideas Educ, 1, 414-418.
40. Malik, K., Tokkas, J., Anand, R. C., & Kumari, N. (2015). Pretreated rice straw as an improved fodder for ruminants-An overview. Journal of Applied and Natural Science, 7(1), 514-520.
41. Malla, M.B. (2004). Chemical composition and feed value of fodder trees from Palpa District, Nepal. Banko Jankari 14: 27-30
42. Mochel F.W., Carneiro, M., Andrade, A., Pereira, E., Andrade, A., Cândido, M., Magalhães, J., Rodrigues, B., Santos, F., & Costa, N. (2016). Yield of Mombaça grass under irrigation and nitrogen fertilization. Revista de Ciências Agrarias, **39**(1), 81–88. https://doi.org/10.19084/RCA14154
43. Moreira, N. (1989). The effect of seed rate and nitrogen fertilizer on the yield and nutritive value of oat-vetch mixtures. The Journal of Agricultural Science, 112(1), 57-66.
44. Norrapoke, T., Wanapat, M., & Wanapat, S. (2012). Effects of protein level and mangosteen peel pellets (Mago-pel) in concentrate diets on rumen fermentation and milk production in lactating dairy crossbreds. Asian-Australasian journal of animal sciences, 25(7), 971.
45. Nuss, E. T., & Tanumihardjo, S. A. (2010). Maize: a paramount staple crop in the context of ```global nutrition. Comprehensive reviews in food science and food safety, 9(4), 417-436.
46. Pathak, N. (2020). Animal nutrition: Desirable characteristics of nutrition, https://www.jliedu.com/blog/animal-nutrition-characteristics/
47. Peterson, P.R., Sheaffer, C.C., & Hall, M.H. (1992). Drought effects on perennial forage legume yield and quality. Agron. J. 84, 774-779.
48. Radwinska, J., & Zarczynska, K. (2014). Effects of mineral deficiency on the health of young ruminants. Journal of Elementology, 19(3).
49. Rand W.M., Pennington J.A.T., Murphy S.P., & Klensin J.C. (1991). Analyzing foods: Part II. Compiling data for food composition data bases. United Nation University Press: The United Nation University, Tokyo, Japan, pp. 19-2
50. Rothauge, R. (2016). Coping with Man-made Drought in Kunene. All Africa.com. The Namibian Newspaper.
51. Rubanza, C. D. K., Shem, M. N., Otsyina, R., Ichinohe, T., & Fujihara, T. (2003). Nutritive evaluation of some browse tree legume foliages native to semi-arid areas in western Tanzania. Asian-Australasian Journal of Animal Sciences, 16(10), 1429-1437.
52. Rusche, W., (2019). Forage Sampling Procedures. SDSU. Extension Beef Feedlot Management ssociate. USDA. South Dakota State University. Sade, F. O. (2009). Proximate, antinutritional factors and functional properties of processed pearl millet (Pennisetum glaucum). Journal of food technology, 7(3), 92-97.
53. Saleh, A. S., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet grains: nutritional quality, processing, and potential health benefits. Comprehensive reviews in food science and food safety, 12(3), 281-295.
54. Sanchez, P. A. (2002). Soil fertility and hunger in Africa. Science, 295(5562), 2019-2020.
55. Sawe, J. J., Tuitoek, J. K., & Ottaro, J. M. (1998). Evaluation of common tree leaves or pods as supplements for goats on range area of Kenya. Small Ruminant Research, 28(1), 31-37.
56. Sayar, M. S., Yavuz, H. A. N., Yolcu, H., & Yücel, H. (2014). Yield and quality traits of some perennial forages as both sole crops and intercropping mixtures under irrigated conditions. Turkish Journal of Field Crops, 19(1), 59-65.
57. Schmidt,J. (2015): A takarmányozás alapjai. Mezőgazda Kiadó, Budapest, 37–45. Schroeder, J.W. (1994). Interpreting forage analysis. Extension Dairy Specialist, AS-1080, North Dakota State University. Souza, M. A. D., Detmann, E., Batista, E. D., Franco, M. D. O., VALADARES, S. D. C., Pina,
58. D. S., & Rocha, G. C. (2017). Estudo colaborativo para avaliação dos teores de matéria mineral em alimentos. Revista Brasileira de Saúde e Produção Animal, 18, 62-75.
59. Sweet, . J., & Burke, A. (2000). Namibia: Country pasture/forage resources profile. alla, 153. Schmidt,J. (2015): A takarmányozás alapjai. Mezőgazda Kiadó, Budapest, 37–45.

60. Tamta, A., Kumar, R. A. K. E. S. H., Ram, H. A. R. D. E. V., Meena, R. K., Kumar, U., Yadav, M. R., & Pandey, A. K. (2019). Nutritional portfolio of maize and cowpea fodder under various intercropping ratio and balanced nitrogen fertilization. Indian Journal of Animal Sciences, 89(3), 276-280.
61. Tedeschi, L. O., Fox, D. G., & Doane, P. H. (2005). Evaluation of the tabular feed energy and protein undegradability values of the National Research Council nutrient requirements of beef cattle. The Professional Animal Scientist, 21(5), 403-415.
62. Thiex, N., Novotny, L., & Crawford, A. (2012). Determination of ash in animal feed: AOAC official method 942.05 revisited. Journal of AOAC International, 95(5), 1392-1397.
63. Tilahun, H., Teklu, E., Michael, M., Fitsum, H., & Awulachew, S. B. (2011). Comparative performance of irrigated and rainfed agriculture in Ethiopia. World Applied Sciences Journal, 14(2), 235-244.
64. Upadhaya, S. D., & Kim, I. H. (2020). Importance of micronutrients in bone health of monogastric animals and techniques to improve the bioavailability of micronutrient supplements—A review. Asian-Australasian journal of animal sciences, 33(12), 1885.
65. Valadares Filho, S. D. C., Silva, L. F. C., Gionbelli, M. P., Rotta, P. P., Marcondes, M. I., Chizzotti, M. L., & Prados, L. F. (2016). Nutrient requirements of Zebu and Crossbred cattle-BR-CORTE. Suprema Gráfica Ltda.
66. Weinberg, Z.G., Yan, Y., Chen, Y.. Finkelman, S., Ashbell, G., & Navarro, S. (2008). The effect of moisture level on high-moisture maize (Zea mays L.) under hermetic storage conditions—in vitro studies, Journal of Stored Products Research, 44(2), 136-144, https://doi.org/10.1016/j.jspr.2007.08.006.
67. Wu, D., Lewis, E. D., Pae, M., & Meydani, S. N. (2019). Nutritional modulation of immune function: analysis of evidence, mechanisms, and clinical relevance. Frontiers in immunology, 9, 3160.
68. Xia, C., Rahman, M. A. U., Yang, H., Shao, T., Qiu, Q., Su, H., & Cao, B. (2018). Effect of increased dietary crude protein levels on production performance, nitrogen utilisation, blood metabolites and ruminal fermentation of Holstein bulls. Asian-Australasian Journal of Animal Sciences, 31(10), 1643.
69. Zhou, H., Yu, B., Chen, H., & Chen, D. (2021). Carbohydrates effects on nutrition and health functions in pigs. Animal Science Journal, 92(1), e13557.