Influence of Fossil Shell Flour Supplementation on Feed Preference, Body Condition Scores and Wool Parameters of Dohne Merino Wethers

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Abstract

Background: The abundance of fossil shell flour (FSF) globally has resulted in an increased interest in its use as a feed additive in sheep diets. This study evaluated the effects of varying inclusion levels of FSF on feed preference, body condition scores and wool parameters of Dohne Merino (DM) wethers.

Methods: Twenty-four wethers, weighing 20 ± 1·5 kg on average were fed dietary food-grade fossil shell flour in a completely randomized design of four treatment with six wethers in each treatment. The wethers were fed a basal diet without FSF addition (control, 0%), or with the addition of FSF (2%, 4% or 6%) into the diet for 105 days.

Results: Average daily weight gain and body condition score of 2%, 4% and 6 % FSF inclusion levels were higher ($P < 0.05$) than the control 0%. Wool yield, staple length, coefficient variation of the fibre diameter and fibre <15% of wethers supplemented with FSF were higher ($P < 0.05$) compared to the diet without FSF. Fibre diameter of the wethers supplemented with FSF were the same ($P>0.05$) as the control.Wethers preferred FSF supplemented diets to the control. The inclusion of FSF in the diet of DM wethers up to 6% DM showed improvement in the average daily gain and body condition scores, feed intake through preference, wool yield, and quality.

Conclusion: The addition of FSF in the diets could be advantageous in Dohne-Merino wethers performance and production with the potential of increasing both the quantity and quality of wool.

1. Introduction

Sheep plays a major part in global agricultural economy through the production of wool and mutton with the world's sheep population estimated to be over 1.173 billion[1]. In South Africa, sheep contributes about 10% of total income from animal products, and wool contributes more than half of the 10%[2]. It is by far the most used natural animal fiber for fabrics, carpets, upholstery, saddle cloths, and horse rugs [3]. Common wool breeds include Merino, Super fine wool, Nilgiris, Chinese Merino, Corriedale, Dohne Merino [4,5]. Among these, the Dohne Merino are known to produce uniform, high quality and fine wool [6]. Around 40% of the total South African wool sheep are Dohne Merino breed [7].

Over the last three decades, the demand for lighter weight fabrics by consumers and competition from synthetic fabrics has made production of quality wool of utmost important to the sheep industry [8]. Fibre diameter, fibre diameter coefficient of variation, comfort factor, fibre curvature, spinning fineness, staple length, staple strength, and clean fleece yield are the major determinants of wool quality [9]. The quality and quantity of wool is determined by factors such as health status of the sheep, nutrition, gender and nematode infection [10]. The health conditions of a sheep affect the volume of wool being produced, staple length (SL), staple strength (SS) and, fibre diameter (FD) [2]. Reduction and pigmentation of fibre diameter and clean fleece weight has been reported to be caused by nematode infection [11].

Strategies such as dosing with anthelmintic have been widely used to control nematodes in sheep, and, thus, improve wool quality and quantity. [12] observed that reduced worm load due to frequent treatment by anthelmintic gives rise to better greasy fleece weight (GFW) and FD. However, the use of chemical-based anthelminthic, has increased anthelmintic resistance especially in South Africa, where sheep farming is becoming unsustainable. Anthelmintic resistance is, thus, fast becoming one of the biggest challenges to wool production. There is therefore a need to employ more sustainable worm control strategies in order to reduce reliance on routine anthelmintic. One such way could be use of natural anthelmintics such as fossil shell flour (FSF), Zeolites and $LaCl_3$ [13]. The FSF is natural and parasites may not be able to develop resistance against it because of certain properties it possesses [14,15]. There are suggestions that FSF powder is characterized by abrasive action that pierces or scratches the outer protective layer of invertebrates including internal parasites resulting in death by dehydration [16].

Gender and physiological status also play a significant role in wool parameters of sheep. [17] reported that higher volumes of fleece were found in wethers than ewes. There have been suggestions that because ewes and rams have low Sulphur-containing amino acids such as cysteine and methionine, they do not produce much wool compared to wethers [18,19]. As a result, many Dohne Merino producers keep a large proportion of their flock as wethers for wool production. Nutrition is another major factor that determines wool characteristics of sheep [12]. [20] and [21] observed that sheep diets with an average of 15% CP improved wool fibre diameter, staple length and growth rate. Body condition scoring (BCS), a strong proxy of nutritional status of sheep, has been reported to have linear relation on wool growth and fibre diameter [22]. High BCS results in greater wool yield. Fibre diameter responds to changes in nutrient availability and average weight gain. Both the macro and micro-minerals have been found to play a major role in wool quality and quantity [19]. An adequate supply of minerals such as Zn, Cu, Fe and pyridoxine is required for production of good quality wool [23].

Pastures in semi-arid and arid regions have low levels of minerals such as Zn, S, Cu and Fe. These low levels of Zn, S, Cu and Fe results in low wool growth rate and poor wool quality [24]. Harsh environmental conditions and redirection of the use of grains from feed to fuel has made supplementation feeding increasingly expensive [25,26]. There is, therefore, a need to explore on supplements that are readily available, cheap and of good nutritive value that can meet this requirement. The FSF, which is rich in trace elements such as Zn, S, Cu and Fe is a possible solution [27]. Therefore, application of FSF may enhance nutritional status of Dohne-Merino sheep.

Fossil shell flour is a deposit of unicellular algae that are made up of fossilized skeletons of diatoms which are either found in ponds, streams, lakes or seas [28]. Fossil shell flour comprises 14 trace minerals such as Mg Zn, S, Cu, Fe, Ca, Mn which can be fundamental for the improvement of feed preference, body condition scores and wool quality of sheep. Fossil shell flour is readily available, cheap and has no adverse effects on sheep for now [29]. Feed preference determine the acceptance of feed hence the intake. Low intake in turn results in reduced wool growth and low staple length, poor fibre < 15% and poor fibre diameter [30]. Against this background, the study investigated the impact of the inclusion of different levels of FSF in the diet of Dohne-Merino wethers on wool growth and quality, body condition score and feed preference. In this paper, we report on the influence of fossil shell flour supplementation on wool parameters, feed preference and body condition scores of Dohne-Merino wethers.

2 Materials And Methods

2.1 Ethical approval

The handling and the use of the animals was approved by University of Fort Hare, Animal ethics and Use Committee [Approval number (MPE041IKU01)].

2.2.Study site description

The experiment was conducted at the small ruminant unit of the University of Fort Hare teaching and research farm, Alice, Eastern Cape, South Africa. The research farm lies at longitude 26º 50' E and latitude of 32°46' S. The annual rainfall is between 480-490 mm and temperature range between 24.6 º C and 11.1 º C (average is 17.8 º C) at an altitude of 535 meters above sea level.

2.3. Sheep and housing

Twenty-four Dohne Merino wethers were selected from a commercial farm in Mitford village, Tarkastad, Eastern Cape of South Africa. The wethers were about 5 months old and weighed 20 ± 1.5 kg on average. The wethers were used in a completely randomized design of four treatments with six wethers per treatment. All the 24 wethers were raised at the same housing and equipment facilities in the same area under the same average environmental condition. The pens had similar temperature (23.29 °C), relative humidity (76.75%), dry bulb temperature (24.82 °C) and wet bulb temperature (21.15 °C). They were individually housed in 1.5 m × 1.5 m well-ventilated roofed building with concrete flooring for each sheep. The experiment lasted for 105 days excluding 14 days of adaptation period. The sheep had access to clean and fresh water ad libitum.

2.4 Experimental Diets

The diets for the wethers consisted of concentrate and hay at 40:60 ratio. The concentrate was made up of maize (8%), sunflower oil cake (10 %), molasses (5%), wheat offal (15%), limestone (1.5%), salt 0.3% and sheep mineral-vitamin premix (0.2%), whereas the hay consisted of 30 % teff and 30 % Lucerne. The ingredients for concentrate were purchased from Monti Feeds (pty) Ltd, East London, South Africa while the teff and Lucerne were purchased from Umtiza Agricultural products (Pty) Ltd, Kwantu shopping mall, Alice, South Africa. All ingredients were thoroughly milled and mixed evenly together to form the basal diet. The feed was formulated to meet the nutritional (energy and protein) requirements of the used sheep (NRC, 2007). The four dietary groups were: basal diet (0%); basal diet +2% FSF; basal diet +4 % FSF and basal diet + 6% FSF. The wethers were fed at 8:00h and 15:00h at 4 % of the body weight (on dry matter (DM) basis). The food-grade Fossil shell flour was purchased from Eco-Earth (Pty) Ltd, Port Elizabeth, South Africa which produces this product under a license by Department of Agriculture, Forestry and Fisheries of South Africa.

2.5 Analytical procedures

2.5.1 Proximate analysis of the experimental diets, orts and fecal sample

The proximate composition of the experimental diet is presented on Table 3.1. Dry matter content of the diets, orts and fecal samples was measured by drying samples in an air-forced oven at 135°C for 24 h [31](method 930.15; AOAC 2005). Ash content was measured by placing samples into a muffle furnace at 550°C for 5h (method 938.08; AOAC 2005). Organic matter (OM) was calculated as the difference between DM and the ash content. Nitrogen (N) was measured by the Kjeldahl method using Se as a catalyst and crude protein (CP) was calculated as 6.25 × N. Gross energy (GE) was measured using a bomb calorimeter (C200, IKA Works Inc., Staufen, Germany). Ether extracts (EE) were measured by weight loss of the DM on extraction with diethyl ether in Soxhlet extraction apparatus for 8h [31](method 920.85; AOAC 2005). Crude fibre was determined by allowing the sample to boil with 1.25% dilute H_2SO_4, washed with water, further boiled with 1.25% dilute sodium hydroxide and the dried residue (65 º C for 3 hours) after digestion was taken as crude fibre (method 978.10) as described by [32]Thiex (2009).

2.5.2. Mineral analyses

The mineral composition of the dietary FSF used is shown in Table 2. In determination of mineral content of the FSF, 5.0 g of the sample was weighed in triplicate, and burnt at 550 º C in a muffle furnace for 5.5 hours. The residues were cooled in desiccator, before dissolving in 100 ml of deionized water. Suitable salts of the elements were used to make their standards. The standard mineral solutions were injected into atomic absorption spectrophotometer (Jenway, FPSP 210 model 6305, United Kingdom) and concentration obtained. These standards were used to determine Mg, Zn, Fe, Cd, Ca, Al, Mn and B in an unknown feed sample. The concentration of Na and K were determined using flame photometer (Jenway Models PFP7 and PFP7/C, Cole-Parmer, United Kingdom).

Table 1
Proximate analysis of the experimental diets

Items	Percentage (%)
Maize	8
Sunflower oil cake	10
Molasses	5
Wheat bran	15
Limestone	1.6
Sheep premix	0.2
Salt	0.3
Grinded leucine hay (alfalfa)	30
Grinded teff hay	30
Chemical composition	
Dry matter (% as fed)	95.5
Organic matter	85.22
Energy ME	24.67
Crude Protein	14.56
Ash	10.33
Ether extract	1.7
Crude Fibre	22.60

Table 2
Mineral composition of FSF

Items	Quantity
DM %	93
Ca	0.40
% CaO (calculated from %Ca)	0.55
Mg	0.21
%MgO (calculated from %Mg)	0.34
K%	0.16
Cu (mg/kg)	30
Na (mg/kg)	923
Zn(mg/kg)	118
Fe(mg/kg)	7944
Mn(mg/kg)	69
P (as P2O5)	0.037
Sulfate Sulfur (S)%	0.062
Aluminum (Al) %	0.065
Vanadium (V) %	0.00438
Boron (B) %	0.0023

2.6. Measurements

2.6.1. Wool samples collection and measurement

An area of approximately 10 cm × 10 cm was shorn on the mid-side left of each wether with a clipper (Oster clippers, No 47cutting head, Germany) on day 0 of the experiment. At the end of the experiment (day 105), a second patch was clipped and wool removedfrom the same spot. Heron's formula was used to measure and determined the patch area as described by [33]. The formula stated as: that area of triangle=√(s-a) (s-b) (s-c), where a, b and c are the sides of the triangle. S is the semi perimeter of the triangle, calculated as S=a+b+c/2. The clipped wool was dried in an oven for 48 h at 60 °C and weighed to determine the total wool weight. Wool growth was determined by the equation: greasy weight (mg)/ area (10×10 cm) divided by number of experimental days. Greasy wool is the wool in its natural state, after removing from the sheep, before any commercial processing. It contains vegetable matters, extraneous soil, yolk, moisture and suint. Greasy weight was determined by near infrared method (NIR). The NIR is a spectrophotometer, which uses near infrared energy to measure the amount of grease remaining in a sample of scoured wool. Samples were then washed at 90 °C with Clean Plus (a mild soap produced by Clean Plus Chemical, Australia), and rinsed twice with cold distilled water to remove impurities and wool grease. This was followed by oven drying at 110 °C for 4 h. Samples were then reweighed at relative humidity of 65% to calculate the clean wool weight [34]. Wool yield was then calculated by determining the percentage of clean wool weight relative to greasy fleece weight, after which they were packed in labelled plastic bag and sent to a commercial laboratory (BKB Wool (PTY) Ltd, Port Elizabeth, South Africa) where fibre diameter, SD, FDCV, CEM, comfort factor, staple length, FD Dev and number fibre <15% were measured according to IWTO 12 norms as described in detail by[34].

2.6.2. Body condition score

The BCS was carried out on weekly basis before the morning feeding by a trained person. The BCS chart was developed based on the system described by [35]. In this method, there is 0.5 intervals for scores ranging from 1 (emaciated) to 5 (obese). Scoring was done by touching redundancy and crossing the amount of muscling and fat deposition over and around the vertebrae in the loin region.

2.6.3. Feed preference

For feed preference test, twenty-four wethers from section were individually housed in pens (5 × 7 m) having four feeding troughs with identification in a completely randomized design with six wethers per diet. The feeding troughs were distributed at equal distance of 0.7 m from one another, and positioned beside one facing the entrance of the pens. Prior to the commencement of the trial, all the wethers were allowed to acclimatize themselves to the pen and feeders for 5 days. After the adaptation period and sequel to an overnight fast, 200 g of each diet 0%, 2%, 4% and 6% FSF was put into the four different feeding troughs in each pen. Each wether in each pen with four different feeding troughs containing four different diet was allowed to access the feeding troughs for ten minutes daily for a period of 7 days. Daily, feed was rotated to a different feeding trough, and each wether was introduced into the pen for 10 minutes, and the order they accessed the various feeding trough was noted. The number of times the wether visit each feeding trough within the stipulated period were determined by counting and recorded as number of visit (NV), number of bites per visit by wether for each diet were determined by counting and recorded as number of bites per visit (NBV). Time spent on visit by each wether on each diet was determined using stop watch (EMC, Zhejiang, China) and recorded as time spent visit (TSV), and the dry matter intake (DMI) for each diet were calculated by multiplying percentage dry matter of the feed with the average daily feed intake. At the end of the 10 minutes, the feed refusal for each feeding trough was weighed to enable the determination of feed consumed. At the end of the preference test, animals received 1 kg of mixture of leucine and teff hay.

2.6.4. Feed intake

Feed intake was determined by weighing the feed leftover in feed troughs, including feed refusals every day at 0800 h. Amounts of feed disappeared were considered to be feed ingested by the wethers. The feeding troughs were design to reduce feed spillages. Weights of feed leftover were subtracted from the total weight of the feed allocated to each wether and divided by 7 to determine average daily feed intake (ADFI) [36]. Dry matter intake was determined by multiply percentage dry matter of the feed with the average daily feed intake.

2.6.5. Average daily gain

Average daily gain (ADG) was measured by weighing the wethers every week throughout the experiment period. The difference in weight of wethers at the beginning and end of each week divided by 7 determined the ADG [37]. To determine body weight gain (BWG), the wethers were weighed weekly, over 14 weeks using RUUDWEIGH, KM-2E electronic weighing system with 0.05 precision (RUUDSCALE, Durbanville, South Africa).

2.7. Statistical analyses

General linear model of SAS 9.4 (SAS Institute, 2012) was used to analyze the effect of FSF inclusion levels on body condition scores, average daily weight gain, fibre diameter, staple length, comfort factor, SD, FDCV, CEM, wool growth, number of visits, number of bites per visit, time spent per visit, and dry matter intake. The model included different inclusion levels of FSF as fixed effects for body condition score, wool parameters and feed preference. The following model was used:

$Y_{ij}= \mu+\beta_i+W_j + (WxB)_{ij}+ E_{ij}$. Where:

Y_{ij} is the dependent variable (BCS, ADG, FD, SL) μ is the overall mean

β_i the effect different inclusion levels of FSF (j = 0 % ,2 % ,4 % and 6 %) W_j is the effet of the jth week;

(WxB)ij is the interaction between week and inclusion levels of FSF; Eij is residual error ~ N (0; Iσ2).

Turkeys' studentized range test was used to test the significant differences between means.

3. Results

3.1 Body condition scoring

The result showed that growth performance had a linear relationship with body condition scores (Table 3). There was a significant effect of the FSF inclusion levels on the body condition score for the wethers ($p < 0.05$). Wethers fed on FSF based diets had highest BCS than those fed on 0 % FSF ($p < 0.05$). Wethers fed on 4 % FSF had higher BCS than those fed on 2% FSF and 6 % FSF ($P > 0.05$, Table 3).

3.2.Wool quality parameters

The effects of FSF inclusion levels on wool characteristics are presented in Table 4. Wethers supplemented with FSF had higher wool growth than those fed on a diet with 0 % ($P < 0.05$). Wethers fed on a diet with 6% FSF inclusion level had the highest wool growth followed by 4%, 2% and 0% FSF ($P < 0.05$). There was no significant difference in wool fibre diameter between wethers fed on diets with 0%, and 4% FSF. Wethers fed on 6% inclusion level had lower wool diameter than those fed on 0% and 4% FSF ($P < 0.05$), but were similar to those fed on 2% FSF ($P > 0.05$). The staple length of wool from wethers fed on diet with 0% FSF was shorter compared to wethers supplemented with FSF ($P < 0.05$). Wethers fed on 6% FSF had the highest value followed by those on 4%, 2% and the least was those fed on 0% FSF ($P < 0.05$).

3.3.Feed preference

The wethers preference to diets is presented in Table 5. The number of visit (NV), number of bites per visit (NBV), time spent on visit (TSV) and the dry matter intake (DMI) were higher ($P < 0.05$) in wethers fed on diets with 2%, 4% and 6% FSF than those on 0% FSF. The feed refusal (FR) were higher in wethers fed diet with 0% FSF than those fed on 2%, 4% and 6% inclusion levels ($P < 0.05$).

Table 3

The initial body weight, final body weight, total body weight gain, and body condition score of wethers for each treatment

Parameters	**Treatments**				**SEM**	**P-Value**
	0 %	**2 %**	**4 %**	**6 %**		
Initial weight (kg)	19.6	19.4	19.5	19.43	0.428	
Final weight (kg)	27.97c	28.57b	31.30a	29.66b	0.4839	0.004
Average daily weightgain (g/d)	84.69c	92.86bc	121.42a	105.35b	9.53	0.011
DMI, g/d	576.29c	546.11d	665.76a	618.84b	11.84	0.0001
Body condition scores (units)	2.87b	3.1a	3.25a	3.13a	0.077	0.1088

abcmean values with different superscript across the row are significantly different ($P < 0.05$). T1 = 0 % FSF diet, T2 = 2 % FSF diet, T3 = 4 % FSF diet and T4= 6 % FSH diet.

Table 4
Effect of different inclusion levels of FSF on wool parameters of Dohne Merino wethers.

FSF inclusion levels (%)					**SEM**	**P-Value**
Parameters						
	0 %	**2 %**	**4 %**	**6 %**		
Wool growth (mg/100cm2/day)	81.4c	96.5b	98.3b	108.7a	2.700	0.042
FD²µm	18.77ab	18.17bc	19.73a	17.46c	0.557	0.110
FD Dev	0.232a	0.96a	0.93a	0.33a	0.509	0.882
SD Dev. (µm)	3.96a	3.300c	3.77a	3.63a	0.225	0.310
FDCV% (µm)	21.23a	19.4ab	18.80c	20.83a	0.624	0.073
Fibre<15 (mm%)	13.66b	14.43b	8.3c	22.73a	0.473	0.05
Comfort factor%	99.46ab	99.66ab	98.8b	99.87a	0.474	0.460
Staple length (mm)	46c	51.32b	51.67b	58.33a	1.170	0.0003
CEM	7.5	6.47	6.8	6.83	2.950	0.511

[abc]mean values with different superscript across the row are significantly different ($P < 0.05$). T1 = 0 % FSF diet, T2 = 2 % FSF diet, T3 = 4 % FSF diet and T4= 6 % FSH diet.

Table 5
Counts of visit by the animal, number of bits per visit, time spent per visit, dry matter intake and feed refusal of wethers for different inclusion levels of FSF

Parameters	**FSF inclusion levels (%)**				**SEM**	**P-value**
	0 %	**2 %**	**4 %**	**6 %**		
NV	2.96c	3.96bc	4.64b	6.75a	0.455	0.0001
NBV	3.17c	4.43c	8.00b	11.54a	0.889	0.0001
TSF	1.96c	2.89b	3.36b	4.82a	0.27	0.0001
DMI	18.82c	36.85bc	45.10b	73.46a	6.576	0.0001
FR	381.18a	363.14ab	354.54b	328.68c	6.751	0.0001

abcmean values with different superscript across the row are significantly different ($P < 0.05$). T1

= 0 % FSF diet, T2 = 2 % FSF diet, T3 = 4 % FSF diet and T4= 6 % FSH diet. NV=number of visits; NBV=number of bites per visit; TSF=time spent per visit; FR=feed refusal; DMI=dry matter intake.

4. Discussion

Body condition scores (BCS) is a good predictor of fat reserves. Increase in body condition scores from 3 to 4 or 4 to 5 units result in greater rate of fat deposit at a subcutaneous level [38]. Several studies have shown a direct relationship between body weight and body condition scores, but there is variation in body weight as BCS increases in different breed of animals [35]. In this study, the BCS followed the trend reported by [35], where BCS of the wethers fed with FSF supplemented diets were different ($P < 0.05$) from the control. The live weight gain comes at an energy cost, and BCS gain also has an energy cost. It therefore implies that wethers in FSF supplemented diets will have more energy reserve for productivity, physiological, and metabolism purposes than those on non-supplemented diets. Also, linear correlation exists between dry matter intake and wool growth [39]. The nature of this relationship depends on nutrients constituent (especially dietary protein) of the diets that are available to the wool follicle, and genetic composition of the sheep[20,40]. [21] reported that wool growth rate and wool quality depends largely on the dietary protein available to the sheep. This present study observed a normal range of protein content for wool growth as recommended by National Research Council [23]. Also, the high content of Zn in FSF helps in the synthesis of Sulphur containing amino acid that promotes wool growth [19]. Similarly, FSF increases the DMI of the feed, which in turn increases the availability of protein for the sheep. It could be observed from our study, that wethers fed on diet with the highest DMI (g/day) (T3 (4 %) and T4 (6 %) had the highest wool growth. This aligns with the report of [26] who observed that addition of mineral supplement to the diet of sheep, increased the clean weight growth even in sheep not selected for wool growth. Wool growth trends were in essence similar to those of body weights, which were consistent with the results of [12] in which different diets were compared. A slight small change was noticed in fibre diameter between the wool of wethers fed on diet with 0 % FSF and those on supplemented diets, while considerable difference was observed between the wool of wethers on 0 % FSF and those on supplemented diets in staple length, FDCV and fibre>15%. This is in agreement with [41], who established that finer wool from ewes showed less variations in the fibre diameter change. The difference in staple length observed in this study could be due to mineral elements such as Zn, Cu and Fe that are present in FSF which has been established to have a major impact on wool follicle growth and quality [42].Copper and zinc function directly in the process of wool growth. Copper is involved in keratinization while zinc is specifically required by rapidly proliferating tissues. The two elements play a vital role in the synthesis of protein [43,44]. [44] reported that Zn concentration of 0.5 ppm in the plasma of Merino lambs supported wool growth. It has been observed that Cu and Zn are involved in continuous and adequate manufacturing of Sulphur-containing amino acids (cystine and methionine) that are needed by the wool follicles to sustain wool growth [18,19]. Methionine function primarily in the provision of cysteine via the transulphuration pathway or by catabolism through the transamination pathway. However, comfort factor, CEM, FDSD and FD

Dev were not affected by the dietary treatments. This aligns with the observations of [45,46] that high Zn intake had no effect on comfort factor, coarse edge micron (CEM) or fiber diameter coefficient of variation.

Wethers fed with the highest amount of FSF produced wool with FD of 17.46 µm. This can be classified as superfine wool, according to Australian Wool Corporation (1990), FD between 15 and 18.75 µm is classed as such. Fiber diameter is a major determinant of wool quality and price and is usually influenced by nutrition in a similar manner to fiber length. The ratio of fiber length to FD is generally constant in sheep housed in pens as they are provided with a consistent supply of the same diet [47].

The wethers visited diets supplemented with FSF more than the control. Also, among the supplemented diets, the number of visits increased as the amount of FSF increases in the diets. This also made the number of bites per visit (NBV) and the DMI in the FSF supplemented diets to be statistically higher than the control. Among the factors that might have influenced feed preference by sheep are flavor, physical outlook of the feeds, taste and particle size of the diets [48,49]. Sheep requires 25 to 40 ounces per head per day of NaCl and will eat less feed when deprived of NaCl [50]. Similarly, it has been observed that minerals such as Na, Ca, K and Mg increase the palatability of diets [51,52]. Also, FSF, Zeolite, bentonite and some dietary clays are rich in minerals that could increase the palatability of livestock diets [53]. This corroborates the result in this current study that FSF is rich in minerals (Na: 923 ppm; Ca: 0.22%; Mg: 0.11%; K: 0.11%) (Table1). Hence, the increase in the number of visits, number of bites by the wethers in the supplemented diets compared to the control could be attributed to the good taste impacted by its richness in dietary minerals including Na, Ca, K, and Mg. It has been reported that Na in the form of sodium chloride in the diets of sheep influences the feed preference through the taste and flavor of the diets [54,55]. In the same way, [56] and [57] reported that Mg, which cannot be stored in the body are involved in energy generating reaction in the tissue of sheep, while Calcium and Potassium are involved in metabolism and body electrolytes balance that secure the health status of the animal vis-à-vis feed intakes. This agrees with the findings of [58] and [59] who both reported that mineral supplementation has positive effects on feed preference vis-a vis the feed intake and the DMI. [42] also reported that addition of mineral supplement to the diets of sheep increases the preference of such feed by the animal.

5. Conclusion

Using fossil shell flour supplementation in the diets (2%, 4 % and 6%) improved dry matter intake, average daily weight gain, and body condition scores as well as influenced feed preference and wool production and quality of Dohne-merino wethers. Among supplemented diets, wethers fed on diet with 4% FSF inclusion level gave the most significant improvement in respect of average daily weight gain, dry matter intake and body condition scores while wethers on 6% FSF diet gave the highest wool yield, staple length, fibre <15% and was the most preferred diet by the wethers. Fibre diameter tended to improve but insignificantly while FSF inclusion made no difference statistically on comfort factors, FD co-efficient of variation, standard deviation of fibre diameter and coarse edge micron (CEM). It is therefore suggested that FSF should be included in the diets of Dohne-merino as it has the potential to improve of wool growth, growth performance and some wool qualities without adversely affecting the sheep.

Declarations

Authors' contributions:

Ikusika, O.O. conceived, planned, and carried out research work, C.T.M., F.N.F, T.J.Z., and A.I.O. reviewed and supervised the research work and the manuscript. A.I.O. provided funds for the research

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Conflicts of Interest:

The authors declare that there is no conflict of interest in the submission of this manuscript.

Data availability:

Data will be made available on request.

Consent for publication:

The authors affirm that the content of this manuscript has not been published or submitted to any journal elsewhere.

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