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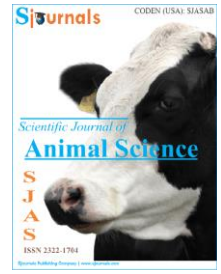

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Original article

Compositional quality of milk and its seasonal variation in Jersey cows of Zimbabwe

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The compositional quality of milk is the outcome of the synergy of various biological processes within the cow and its external environment. The objective of this study was to investigate the effect of season on the compositional quality of milk in Jersey cows of Zimbabwe. The study material consisted of 813 records of a total of 60 head of Jersey cows collected from a commercial dairy farm in Matabeleland South province in Zimbabwe. For the analysis three seasons were defined: 1-Warm Wet (December-March), 2-Dry Cool (April-August), and 3- dry hot (August-November). Chemical compositions (fat, protein, lactose, SNF, salt) as well as the freezing point, density of collected milk samples were carried out by using the Milk Analyzer (Lactoscan, UK). Statistical data processing was carried out by applying the General Linear Model procedure, SAS system (1999). Duncan multiple range test was used to compare the means within a group, difference was considered as significant if (P≤0.05) and the results were presented as Mean±SE. The mean fat percent were 4.94±0.05, 4.62±0.08, and 4.56±0.05, and mean protein percent were 3.72±0.02, 3.50±0.03, and 3.49±0.03 for warm wet season(December-March) dry cool season (April-August), and dry hot (August=November), respectively. The warm wet season had maximum milk urea nitrogen (17.24 ±0.54mg/dl) while the dry cool season (April-August) had the minimum milk urea concentration of 12.38±0.82. The results showed that milk collected in the warm wet season (December-March) had significantly higher fat and protein as compared to dry cool season(April-August) and dry hot (August=November). However, no seasonal variation was evident in total milk solids (TS; %), solids non-fat (SNF, %), and milk density. Moreover, lactose (4.74%) contents were high in the dry hot season (August-November), while maximum milk urea nitrogen content (17.24%) was observed in the wet warm season. The mean concentration of milk urea nitrogen in the study of 14.84±4.60 mg/dl indicates a good balance of energy and protein in the diet. Fat, protein, lactose, and milk urea nitrogen contents of milk significantly varied with the season. Synchronous changes in protein and fat percent in raw milk were much more distinct as the season progresses through the wet and dry season.

1. Introduction

Milk composition is the interplay of many elements within the cow and its external environment. (O'Callaghan et al., 2016) and seasonal fluctuations are quantitatively significant in milk composition due mainly to changes in diet (Chen et al., 2014). The season of the year is a determinant of milk composition by virtue of direct effects on the dairy animal (temperature, humidity, and photoperiod) or indirectly as a result of seasonal changes in pasture quantity and quality. Hence, by extension is the result of the synergy of different physiological, climatic, and feeding factors during the whole of the year. Increased ambient temperature reduced the dry matter intake resulting in differential milk composition (Bhatta et al., 2014). Bansal et al. (2009) reported that fat and protein content was higher in mid-April than in early February whereas lactose content was higher in early February than in mid-April. In summer milk showed better quality regarding milk proteins as compared to winter a difference which is likely due to different animal feeding during summer and winter. The decreased protein percent in hot weather was ascribable to a reduction in β-casein and αs-casein (Bernabucci et al., 2002). Wylie (1925) reported a high fat percent of 5.45 during the months of July, September, and August, while Azad et al (2007) observed the highest milk production in February and lowest in September accompanied by maximum fat and SNF contents in December to April. The aim of this study was to investigate the effect of season on the variations of raw milk composition in Holstein cows in Zimbabwe.

2. Materials and methods

The present study was conducted at a commercial dairy farm in Matobo District in Matabeleland South province of Zimbabwe (20°58'54.43"S, 28°29'11.03"E). The farm is located in southwest Zimbabwe, an area essentially suitable for semi-extensive forms of land usage (Van Rooyen et al., 2007). The climate is designated by wide fluctuations in the quantity and distribution of rainfall within and across the season. The mean recorded rainfall is 609 mm with a range of 257 to 1376 mm. Rainfall normally occurs between November and April and is followed by a long dry season. Very high summer temperatures, maximum and minimum mean temperatures of hottest months are 21.6 0 C and 11.4 0 C, respectively with the possibility of severe droughts (Homann et al., 2007). An elaborate description of the climate and vegetation pattern has been reported (Day et al., 2003; Gambiza and Nyama, 2000).

All animals were fed a mixed ad libitum ration containing grass, maize silage and commercial concentrate twice a day. Animals were left to graze in paddocks for time of the day utilizing pastures and greens in the rainy season, while preserved forages and supplementation were also fed in the dry season. Cows were milked by hand milking system, twice daily. The age of all the animals enrolled in the study ranged from 3 to 6 years.

A total of 813 records from 60 herd of Jersey cows were collected for analysis of milk constituents using the Milk Analyzer (Lactoscan, UK). The milk composition parameters namely fat, protein, lactose, solids non-fat, total solids and milk urea nitrogen were determined. For the analysis three seasons were defined: 1-Warm Wet (December-March), 2-Dry Cool (April-August) and 3- dry hot (August-November).

Milk composition was analyzed using General Linear Model (GLM) procedure of Statistical Analyzed (SAS Version 9.1) (1999). Duncan multiple range test was used to compare the means within a group, difference was considered as significant if (P≤0.05) and the results were presented as Mean±SE. The model employed was as follows:

$Y_{ik} = \mu + A_i + e_{ik}$

Where:

Y_{ik} = Response variables (raw milk composition),

μ = Overall mean,

A_i = treatments: seasonal effect (Warm Wet Season(December-March), 2-Dry Cool Season (April-August), Dry Hot Season (August-November); and

e_{ijkl} = residual effect.

3. Results and discussion

3.1. Milk protein

The analysis of variance showed a significant (P≤0.05) seasonal effect on milk protein percent in Jersey cows. The overall mean of milk protein percent in different seasons were indicated in Table 1. The highest mean protein percent was recorded as 3.72±0.05 in the milk of warm wet season (summer) (December-March) followed by 3.50±0.03 in dry cool season (winter) (April-July) milk and 3.49±0.03 in the dry hot season (Autumn) (August-November). Protein percent ranged from a minimum value of 3.49 ± 0.03% observed in autumn and the maximum value of 3.72 ± 0.02% was observed in summer (rainy season). The values of protein percent in the present study were within the range of values observed by Maha et al (2016) of 2.13 to 4.02% with a mean of 3.58% working with Oulmes breed, but higher than the protein percent range of 2.91 to 3.53 reported by Feltes et al. (2016) in Holsten breed cows in Brazil. Elsewhere lower values of milk percent were reported for Holstein cow milk of Lordegan, region of Iran (3.30%) (Imran et al 2008) and then that observed in Chinese Holstein cows in Northern China (3.10%) (Ponka et al., 2013). Also, the values observed in the current study are on the upper side regarding those reported by Imran et al. (2008) in Pakistan (3.28%), Ponka et al. (2013) in Cameroon (3.26%), and Cofani et al. (2009) in Brazil (3.27%) (Pougheon and Goursaud, 2001; Sanz et al., 2009). The milk protein percent standard by Food and Drug Administration (FDA) has been set at 2.73% (Raff, 2011), while European Union set the standard for unprocessed whole milk total protein content should not be less than 2.9% (Tamime, 2009). It should be noted that the variation in milk protein in different studies might not be due to season but due to the use of different dairy breeds, differential feeding regime and probably differences in animals on stage of lactation. However, in this case, the mean protein percent in the current study was within the expected set standards in Jersey cattle.

In the present study, differences between the mean protein percent in dry cool season (Winter) (April-July) 3.50±0.03 and dry hot season (Autumn) (August-November) 3.49±0.03 were non-significant (p>0.05) whereas, it was significantly higher in the warm wet season (summer) (December-March) 3.72±0.05. In support of the current results, Nobrega and Langoni, (2011) reported similar results that in the dry season, Holstein and Jersey's cows had estimated marginal means of 2.87% and 3.32% protein in the milk, respectively, while in the rainy season, these values increased to 3.01% and 3.52%, respectively. Our result is in agreement with that reported by Heck et al. (2009) and Fox and M^c Sweeney (2003) who reported that protein was constantly lower during autumn as opposed to spring and winter. Elsewhere, Cheruiyot et al. (2018) observed that casein content was higher in milk sampled in the wet season (3.27%) as compared to the dry season (2.88 %). The current results are also in conformity with the previous result by Feltes et al. (2016) who reported depressed protein levels in autumn and winter as compared to cows who dropped their calves in spring and summer. Furthermore, Nobrega and Langoni (2011) reported that protein percent in addition to other milk quality parameters increased in the rainy season for different breeds. The low protein percent in the present study during the dry hot season (Autumn) (August-November is expected because, with the growth of fodder, there is a turndown in protein content in the dry hot season while the crude fiber in the forage increases accordingly. The increased crude fiber favors the synthesis of fat than protein due to the presence of more acetic acid and butyric acid (the resources of fatty acid) which are major precursors of mammary gland synthesis of fat.

For Zimbabwe, December to March is the warm wet season, where the highest fat, protein, and total milk solids were recorded (Table 1), although there was no significant effect of season on total solids. The elevated protein level in the warm wet season (summer) (December-March) might be a reflection of the quality and quantity of feed (forage) utilized during this part of the year. Thus, it can be assumed that the decisive influence on the content of protein in milk assessment was due to the magnitude of pasture derived from the veld, i.e. from pasture in the summer as opposed to the winter period. The period of the study (2020-2021) was characterized by a good rain season and it is more likely that the grazing was abundant distorting the forage to concentrate ratio in the diet hence this could have influenced milk protein percent in summer.

High forage intake in summer may increase microbial protein escape from the rumen which is a major determinant of milk protein synthesis (Bergouignan et al., 2013). On the other hand, milk protein synthesis is generally influenced by energy supply and equity of amino acids supplied to the mammary gland. Highly fermentable diets, without reduction in ruminal pH, supply increased propionate, which is the major source of energy and directly associated with milk protein synthesis. High forage intake in summer may optimize microbial protein synthesis and in this case, microbial protein has a greatly preferable balance of amino acids that optimize milk protein synthesis. The present study demonstrates that dry hot seasons go along with a state of inadequate forage supply and/or in difficult grazing conditions hence the need for dairy concentrate. Leaver et al. (1996), observed that compositional quality of milk response to dairy concentrate supplementation at pasture is dependent mostly on forage supply and quality, the season of the year, stage of lactation, level, and type of concentrate, and milk yield potential of the cow.

In the current study, the milk protein elevation during the summer is likely attributable to warmer environmental temperatures, which could have compromised milk yield hence elevating milk protein due to their negative correlation, as milk yield is depressed, milk protein tends to increase. High environmental temperatures, above 29ºC, have been suggested to depress milk protein percentage, but cows offered cold water (10ºC) during heat stress do not show increased milk protein concentrations over cows offered 28ºC water (Milam et al., 1986). Temperature is a major seasonal aspect that influences milk composition indirectly. The decrease in protein percentage dry hot season (Autumn-August-November) (3.49±0.03) in the current study is expected because it also is attributed to the direct effects of heat stress on the synthesis of the mammary gland (Cowley et al., 2015). A decline in milk protein percent was experienced at a mean daily temperature above 14°C and mean daily THI above 55 in Piacenza province (Po valley) (Casati et al., 1998). In the present study, milk protein was depressed during the dry hot season (3.49±0.03) and this corroborates with other studies, Abeni et al. (1993) reported a decrease in milk protein content when the temperature-humidity index value was higher than 75 (3.02 g/100 g for temperature-humidity index < 75 vs. 2.89 g/100 g for temperature-humidity index > 75, respectively). For, Zimbabwe the heat gradually builds and peaks in October. The first rains can fall by late November, bringing relief from very dry conditions. The lower-lying areas get very hot with temperatures of 32°C/90°F and well above hence, this may influence milk production. The dry hot season (August to November) had the lowest protein percent which conforms to the reports by Cowley et al. (2015) who found that cows exposed to heat stress produced milk with less protein than cows housed in comfortable temperature conditions. Their results suggest that the decrease of milk protein content is mostly related to a direct effect of heat stress instead of a reduction of feed intake. In the current study milk protein was at its lowest level between August-November (autumn), this is probably because of dry hot weather and high humidity that decrease intake of feed energy with in-door feeding and may reflect the particular feeding regime used for some dairy herd.

In contrary to the results in the present study the milk of cows of different breeds fed in a TMR system had pleasant chemical composition in the autumn/winter season (Brodziak et al., 2012; Krol et al., 2010; Strzalkowska et al., 2010). Ayub et al. (2007) also reported higher protein percent in winter as compared to summer. The lowest value of protein was observed in the summer and the greatest value was observed in the winter (Bernabucci et al., 2015). Elsewhere, Colombari et al. (1999) reported that the decline in milk protein was a result of inadequate intestinal absorbed protein, which in turn could be due to very limited rumen undegradable protein content in the diet accompanied by an excess of soluble nitrogen. Therefore, understanding of seasonal variation in terms of forage quality, accompanied by appropriate nutritional management aspects of both ration formulation and feeding management can improve milk protein percent.

Table 1
Least squares means and standard error of the mean (SEM) of milk composition in samples (n = 813) collected from 60 Jersey cows in different seasons.

Trait	Season	Mean	SEM
Fat, %	Wet Warm (December-March)	4.94[a]	0.05
	Dry Cool (April-August)	4.62[b]	0.08
	Dry Hot (August=November)	4.56[b]	0.05
Protein, %	Wet Warm (December-March)	3.72[a]	0.02
	Dry Cool (April-August)	3.52[b]	0.03
	Dry Hot (August=November)	3.49[b]	0.03
Lactose, %	Wet Warm (December-March)	4.70[a]	0.01
	Dry Cool (April-August	4.64[b]	0.02
	Dry Hot (August=November	4.74[a]	0.02
Solids Non-fat, %	Wet Warm (December-March)	9.14[a]	0.04
	Dry Cool (April-August	9.03[a]	0.07
	Dry Hot (August=November	9.18[a]	0.05
Total Solids, %	Wet Warm (December-March)	13.99[a]	0.10
	Dry Cool (April-August	13.65[a]	0.15
	Dry Hot (August=November	13.73[a]	0.11

[a,b,c] Means with different superscript within each milk component are significantly different (p-value < 0.05).

3.2. Milk fat

Lipid is one of the main components of milk. The dominant fraction of milk fat is TAG (about 98%) present in the form of fat globules (Mansson, 2008). Variation in fat content from season to season is reflected in Table 1. The highest mean milk fat percent was recorded as 4.94±0.05 in the warm wet season (summer) (December-March) followed by 4.62±0.05 in the dry cool season (winter) (April-July) and 4.56±0.05 in dry hot (August-November) season milk. Fat percent ranged from a minimum value of 4.56 ± 0.05% observed in autumn and the maximum value of 4.94 ± 0.05% was observed in summer (rainy season). A similar result was reported by Sharma et al. (1985) that the overall mean for the fat content of milk was 4.53 percent which was almost comparable to 4.70 with this study. The present fat percent values are higher than the averages of several breeds reported as 2.6, 4.18, 2.01, 3.79, 3.76, and 3.63 for Boran, Nguni, Tuli, Afrikaner, Bonsmara, Drakensberg, respectively (Myburgh et al., 2012). However, the fat content of milk for Jersey cows in the present study (Table 1) is within the range for the milk composition standard requirement for cows of 3.5 - 5.0% (Anantakrishnan et al., 1993). Furthermore, lower values than the current study were reported elsewhere by the AFNOR value (3.04%) (Cofani et al., 2009), Brazil (3.63%) (Sanz et al., 2009) in Brazil, and (3.25%) (Mapekula et al., 2011; Heck et al., 2009) in the milk of local Nguni cattle in South Africa.

High milk fat values, which conform with the present study were reported in Dutch raw bovine milk, with a maximum of 4.57% in January. However, our average in the present study (4.74%) is lower to 6.09% found in autumn as a maximum value of fat by Fox and Mcsweeney (2003). Furthermore, milk fat percent in the current study is partly within the range reported by Maha et al (2016) of 2.13 to 4.02% with a mean of 3.58%. working with Oulmes breed. Also, Nevens (2010) reported fat content in five dairy breeds (Ayrshire, Brown Swiss, Guernsey, Holstein, and Jersey) which ranged from 3.41% to 5.06%. The high milk fat value in the present study was ascribable to differential temperatures and feed composition through the wet and dry seasons. For the European Union quality standard for raw milk, the fat content should not be less than 3.5%, while the Food and Drug Administration (FDA) sets it at not less than 3.25% milkfat for fluid whole milk. Therefore, the fat percent in the Jersey cows of Zimbabwe was of an acceptable standard (Raff, 2011).

Differences between seasons for average fat percent were statistically significant (P≤0.05), except for the difference between dry cool season (Winter-April-July) (4.62±0.08) and dry hot season (Autumn-August-

November) (4.56±0.03) were not statistically significant (p>0.05). Similar findings were observed by (Nobrega and Langoni, 2011) were for the rainy season, the values increased to 3.25% and 4.50%, for Holstein and Jersey cows, respectively. Partly in support of the present results Ozcan et al. (2015) and Çobanoglu et al. (2017) reported the lowest values of total fat in the winter season of 3.64 and 3.72, respectively. The seasonal variation of milk composition is on account of synthesis and secretion of fat as a complex outcome influenced by the interaction of diverse elements such as climatic conditions, nutritional and physiological status of dairy animals. Furthermore, the inadequate feed consumption and distorted nitrogen energy balance in hot summer months lead to serious fat mobilization from the body hence low milk fat.

For Zimbabwe, in December the nights and mornings are warm at around 18°C/64°F. Afternoon temperatures are around 30°C/86°F and the humidity is high, making it feel hotter hence this has an indirect effect on milk fat synthesis. Some reports cited heat stress being the cause of a decline in total fat content (Liu et al., 2017; Hill and Wall, 2015). There is a tendency of a reduction in milk fat concentration as a result of hot weather (Hammami et al., 2015). However, some authors found no significant decrease in fat percentage for cows under heat stress (Roman-Ponce et al., 1977; Knapp and Grummer, 1991; Lacetera et al., 2003). Prathap Pragna et al. (2017) reported that high temperatures induced stress can result in elevated dairy cow's body temperature which may influence the fat synthesis in the mammary gland hence impacting milk composition. Indirect seasonal effects on milk yield and composition through rising temperatures in dry hot months in Zimbabwe may result in reduced feed intake by animals, apart from the temperature influence on hormonal changes and possibly proliferation of pathogenic infections, as a result, compromising udder health, in turn, depressed milk fat. Key et al. (2014) noted that increased body temperature resulted in lowered milk fat, with the condition being critical when high temperatures are accompanied by low relative humidity. In response to high temperatures, dairy animals have compromised buffering capacity due to elevated respiration, panting, and sweating, and this may necessitate the adaptation in diet composition and feeding practices to counteract milk fat depression. However, on the contrary, Cowley et al. (2015) did not find any significant differences in milk fat content between cows in normal conditions or subjected to heat stress.

The fat percent in this study tend to distinctively respond to wet (warm wet) and dry season (dry cool and dry hot) which indicates that the seasonal variation of fat percent in this dairy herd was more influenced by the changes in quality and quantity forage changes. Feeding systems and seasonal variation are major determinants of milk composition especially fatty acids (Frelich et al., 2012). During summer the feeding strategy is focused on maximizing pasture where consumption of fresh feed and an abundance of greenery contribute to an increase in milk fat. The higher summer fat percent than in winter in individual cows was explained as a partial effect of lactation stage, fresh grass availability (Elgersma et al., 2004; Elgersma et al., 2006), or a seasonal effect (Soyeurt et al., 2008). This is an indication that feeding interventions can lead to large changes in milk fat composition. Large between-year differences may influence milk composition through forage availability, quality, and intake. Woolpert et al. (2017) reported that the physical characteristics of the diet are related to de novo fatty acid and fat concentration in bulk tank milk from high-producing Holstein dairy farms. The effect of the season is confounded as a result it might be essential to identify the causal factors for the observed changes, as these may offer opportunities to improve milk fat composition in the winter and result in a more constant composition and more constant herd performance throughout the year. In the current study, it was noted that fat percent was at its lowest in spring-autumn due to poor quality grazing, and this generally reduces milk fat, while hot weather and high humidity decrease dry matter intake and consequently energy intake, which in turn can reduce milk constituents. For Zimbabwe, dairy animals tend to be supplied dry feed in winter, and green fodder in summer as they are outside for a long time (Louwrens et al., 2000).

Numerous studies point to a higher concentration of biologically active substances in the fat fraction of milk coming from cows fed in the traditional way i.e. using the pasture (Carroll et al., 2006; Morales-Almaráz et al., 2011), which might be applicable to the present dairy herd which experienced highest fat percent in summer. Elsewhere, a higher milk fat fraction in grazing cows' milk is attributed to the higher content of bioactive components in fresh forage. Carroll et al. (2006) stated that not limited (ad libitum) access to the green feed (pasture) causes the increase in valuable milk components i.e. in the not saturated fatty acids and the share of the total solids. The general effect of decreasing the forage to concentrate ratio on rumen fermentation is to decrease pH, increase propionic acid production, and reduce fiber digestion. Thus, as forage declines, milk fat percentage falls proportionately; however, milk fat yields may increase (Sutton, 1980). The critical forage to concentrate ratio appears to be about 40:60, beyond which additional concentrate drastically lowers milk fat percentage (Coppock, 1985). However, Sutton (1980) reported that the actual level of forage needed in a diet to maintain normal milk fat percentage may be affected by total feed intake. At high levels of intake, more forage is needed than at low-intake levels to maintain the same milk at percentage.

Milk fat synthesis is dependent on the supply of acetate from the rumen therefore any plan of nutrition, such as high grain feeding which lowers the production of rumen acetate, will also lower the fat content of milk (Yildirim and Cimen, 2009). There is a tendency of feeding high grain feeding in Zimbabwe during this dry period. Fat is the most variable parameter among the major milk components and its synthesis is affected by many factors-especially dietary and environmental factors (Bayril et al., 2010). Due to high temperatures, heat stress depresses saliva production, which as a result affects the buffering capacity of the rumen. This process reduces ruminal pH hence reducing milk fat. Depressed milk fat is a consequence of management practices that changes dairy animal feeding patterns or behavior. In summer there is a need to adjust dietary regime taking into account the influence of season on forage quantity and quality which may influence dry matter intake.

On the contrary to the current result, fat content was significantly higher (3.97%) in the dry season than in the wet season (2.59%) (Cheruiyot et al 2018). Elsewhere, Bernabucci et al. (2015) reported a marked and significant decrease in milk fat during summer (3.20 g/100 g) compared with the values observed in winter (3.80 g/100 g) and in spring (3.61 g/100 g). Also, Summer et al. (1999) observed a decrease in milk fat content during summer when compared with autumn, ranging from a minimum in June-August (3.36 to 3.38 g/100 g) to a maximum in November (3.67 g/100 g). Seasonal variations in milk fat percentages were well recognized, with summer months averaging 0.4 percentage units less than winter months (Jenness, 1985). For fat, the lowest value was observed in the summer and the greatest value was in the winter (Bernabucci et al., 2015). Furthermore, Verma et al. (2018) reported a mean fat percent of 3.83, 3.68, and 3.64 for winter, summer, and their rainy season in organized farms. While unorganized farms also followed a similar significant trend where winter had a higher milk fat percent than the summer season.

Table 2
Ratio of protein to fat in samples (n = 813) collected from 60 Jersey cows in different seasons.

Season	% Fat	% Protein	Ratio of Protein and Fat
Wet Warm (December-March)(Summer)	4.94	3.72	0.75
Dry Cool (April-August)(Winter)	4.62	3.50	0.76
Dry Hot (August=November)(Summer)	4.56	3.49	0.77
Average	4.70	3.57	0.76

Table 3
Least squares means and standard error of the mean (SEM) of milk urea nitrogen (mg/dl) in samples (n = 813) collected from 60 Jersey cows in different seasons.

Season	Mean	SE
Wet Warm (December-March)	17.24^{a}	0.54
Dry Cool (April-August)	12.38^{b}	0.82
Dry Hot (August=November)	13.08^{b}	0.62
Average	14.24	

^{a,b,c} Means with different superscript are significantly different (p-value < 0.05).

3.3. Protein and fat ratio

The present study observed a mean protein and fat ratio of 0.76, of which the highest protein and fat ratio was recorded as 0.77 in the dry hot season (August-November) followed by 0.76 in dry cool (winter) (April-July), and the lowest was recorded as 0.75 in the milk of warm wet season (summer) (December-March). The protein to fat ratio was within the acceptable range, indicating a sign of high milk protein in cow's milk produced in Zimbabwe. Schroeder (2012) suggested that if the milk protein-to-milk fat ratio is less than 0.80, this is a sign of milk protein depression (low milk protein test) and when this ratio is greater than 1, the problem is from milk fat depression (low milk fat test). Elsewhere, Wangdi et al. (2018) working with dairy cattle in Bhutan reported a lower mean protein to milk fat ratio of 0.65.

3.4. Lactose

The principal carbohydrate in milk is the disaccharide lactose. Several enzyme activities and carbohydrate metabolites together form the fundamental framework of the lactose synthesis pathway (Bartley et al., 1966; Kuhn et al., 1980). The quantity of glucose arriving at the udder determines how much lactose is produced, hence what volume of milk is produced. The highest mean lactose percent was recorded as 4.74± 0.02 in the milk of cows in the dry hot season(August-November) followed by 4.70±0.01 in the milk of cows in the warm wet season (summer season) (December-March) and 4.64±0.01 in the milk of cows in dry cool season (winter) (April-July) (Table 1). The presented level of milk lactose ranged from 4.64 to 4.74 % with a mean of 4.7%. Generally, milk is constituted of 4.9% lactose (Haug et al., 2007; Poulsen et al., 2012). The current result was lower than those reported by Bekele (2015) 5.07% from urban and peri-urban vicinity of Dangila town Amhara region but, to a degree proportionate with the report of Derese (2008) 4.52% and 4.37% in urban and peri-urban area, respectively in west Shoa zone Oromia region in Ethiopia. Elsewhere, O'Mahony (1998) working with dairy animals in Bhutan reported mean lactose content of 5.48, notably higher than reported in the present study.

Lactose percent was significantly (P≤0.05) higher in the dry hot season (August-November) (4.74±0.02) and warm wet season (December-March) 4.70±0.01 than the dry cool season (April-July) (4.64±0.08). This result was similar to the findings of Desyibelew and Wondifraw (2019) in Ethiopia where lactose content in their study was 4.3% and 4.44 % in the winter and summer season, respectively. Elswhere, Zaman et al. (2016) reported a similar trend of the minimum value for lactose percent of 4.46% in winter and a maximum value of 4.49% in summer (rainy season). The current result is in close agreement with those reported by Baul et al. (2014) who reported that milk lactose percent from the lowest to highest of 4.58, 4.68, 4.71, and 4.78% in winter, spring, autumn, and summer, respectively.

The lactose content seemed to respond to the temperature differential of the hot versus cool season. However, the significant (p<0.05%) difference in milk lactose in the warm wet season (summer) (December-March) 4.70±0.01 and dry cool season(winter) (April-July) (4.64±0.08) could be also explained by nutritional factors as it relates to summer and winter, acting as quality and quantity of feed and order of concentrate and forage feeding, which considerably increase or reduce lactose yield by affecting arterial glucose supply to the mammary gland (Stelwagen, 2020). High temperatures have been associated with changes in the endocrine status of dairy animals which impair rumination and nutrient absorption and elevate maintenance requirements (Collier et al., 2006), resulting in a net decrease in nutrient/energy availability. The favorable climatic condition in the warm wet season (summer) (December-March) accompanied by abundant fodder may encourage higher feed intake which might increase the lactose content of milk. On the other hand, this is expected because the changes in lactose percentages during hot weather could be attributed to the reduction of dry matter intake, and consequently, energy intake, which in turn could have in influenced the reduction of milk synthesis. (Zeinhom et al., 2016). Stelwagen, (2020) suggested that temperatures on either side of the thermoneutral zone and high relative humidity have been shown to lower milk lactose yield.

In contrary to our findings, Painkra (2007) reported a higher lactose percentage in the spring season followed by the pre-monsoon season and lowest in the summer season. Elsewhere, in the dry season, Holstein and Jersey's cows had estimated marginal means of 4.40% and 4.46% regarding lactose rate in the milk, respectively. In the rainy season, these values decreased to 4.33% and 4.31%, respectively (Nóbrega and Langon, 2011). Bernabucci et al. (2015) reported the lowest lactose values in summer, while in the present study the lowest value was observed during the dry cool season (winter). In the present study higher value of milk lactose percentage during the winter season could be attributed due to better availability of green fodder and adequate grazing area during the winter season as compared to the summer and rainy season. In contrast, insignificant seasonal variations were recorded in the values of lactose by Heck et al. (2009).

3.5. Milk urea nitrogen (MUN)

Statistically significant differences (P≤0.05) in MUN were shown in the wet and dry conditions concerning the season (Table 1). There was a non-significant (<0.05) difference of MUN concentration due to season for the dry cool season (April to July) and dry hot season (August to November), however, these significantly differed with the warm wet season (December and March). The MUN concentrations were 17.24±0.54, 12.38 ±0.82, and 13.08± 0.62

mg/dl in the wet warm season (December-March), dry cool season (April-August), and dry hot season (August=November), respectively. MUN concentration was lowest in Dry Cool (April-August) (12.38±0.82 mg/dl) and reached a maximum in the warm wet season (December-March) of 17.24 ±0.54mg/dl. MUN values were lowest in the dry cool season (April-August) (12.38±0.82 mg/dl), and start rising through the dry hot season (August-November), with the highest values being experienced between in wet warm season (December-March). For commercial dairy farming in Zimbabwe in light of that animals at this time of the season for all intent and purpose spent much of their time grazing, i.e. at pasture plus dairy concentrates, it can be assumed that their protein intake was high from grazing through this end resulted in higher urea concentrations in milk.

In this work MUN ranged from 13.08±0.62% to 17.24±0.54% MUN with an average of 14.84±4.60 mg/dl, thus, meeting the limits suggested by Ruska and Jonkus (2014). Also, the results are within the range suggested for this parameter (between 10 and 14 mg/dL), and consistent with several review studies (Rajala-Schultz and Saville, 2003; Johnson and Young, 2003; Meyer et al., 2006; Cordeiro et al., 2007). Furthermore, the MUN concentrations are also within the range reported for dairy herds in the USA which are about 12 to 14 mg/dl (Jonker et al., 2002), in Sweden about 11 to 15 mg/dl (Carlsson and Pehrson, 1994), and in Korean dairy cows are 16.68 + 5.87 mg/dl (Yoon et al., 2004). Elsewhere, for Holstein-Friesian, Brown Swiss, Simmental, and Alpine Grey, Gottardo et al. (2017) reported MUN averages of 19.09, 21.03, 19.81, and 20.95 mg/dl, respectively. These were significant among study breeds and higher than current results. Furthermore, sources in the literature indicate different physiological values of urea concentration in milk, which vary from 10 to 30 mg/dl or from 1.7 to 5.0 mmol/l by Marenjak et al. (2004), while Young (2001) reports 12 to 16 mg/dL as a recommended urea concentration in cow milk.

Urea concentration in milk is a presumably a good measure of the balanced diet as regards energy and protein ratio. The energy and crude protein supply are at optimum level if the protein content is within normal ranges of 3.2-3.8 %), and urea concentration is between 15-30 mg/100 ml. The mean concentration of milk urea nitrogen in the study of 14.84±4.60 mg/dl indicates a good balance of energy and protein in the diet. Our observations on MUN were consistent with those reported by Carlsson et al. (1995) and Godden et al. (2001) who cited a higher MUN concentration in the summer. However, our observation was in disagreement with those reported by (Yoon et al., 2004), who reported that milk urea nitrogen concentrations of milk produced in summer and fall were significantly lower than those in spring and winter. Also, Fatehi et al. (2012) reported that MUN concentration was lower in December (13 mg/dl), and reached a maximum in July of 18.8 mg/dl.

In the current study, the mean concentration of milk urea nitrogen was 14.84±4.60 mg/dl, which is with the normal MUN values range from 10 to 14 mg/dl reported by several authors (Jonker et al., 1998; Johnson and Young, 2003; Rajala-Schultz and Saville, 2003). However, the MUN experienced in the warm wet season (December-March) (17.24± 0.54 mg/dl) seemed to be on the higher side. Ivanković et al. (2015) working with both small and large farms reported higher MUN as compared to the present study of 15.87mg/dl and 22.98 mg/dl for small and large farms, respectively. In their study, MUN produced during the fall and winter were (18.69 mg/dl; 18.27 mg/dl) was significantly lower as compared to those produced during the spring and the summer (23.53 mg/dl; 24.39 mg/dl).

It should be noted that both low (Roseler et al., 1993) and high (Payne and Payne, 1987) MUN concentrations is evidence of an underlying nutritional problem. High MUN has been associated with excessive rumen degradable protein (RDP) and/or rumen undegradable protein (RUP) in the diet, which compromises the rumen fermentation rate of non-fiber carbohydrates (NFC) or increased CP: NSC ratio. Godden et al. (2001) suggested that low levels of MUN may be attributable to CP deficiency in the diet, insufficient dietary amounts of RDP and RUP, or elevated NSC fermentation rate in the rumen. In a similar study, it was observed that balancing energy and protein is critical to prevent the body from excreting large amounts of nitrogen (Pina et al., 2006). These findings were supported by Oltner and Wiktorsson (1983) and Hoffman and Steinhöfel (1990) who proved that the variations in protein intake did not influence MUN when the protein-energy ratio was maintained. The probable reason for high MUN in the warm wet season (December and March) is that pasture tends to be rich in protein (more than 20% of CP), and probably poor in soluble carbohydrates, thus creating an increased protein-energy ratio, which can result in high MUN concentrations. According to Moller et al. (1993), greater variation in milk urea nitrogen among grazing cows is due to seasonal variations in pasture protein and amount of fibrous carbohydrates. The trend of fat and MUN values in the present study tends to support the results from Arunvipas et al. (2003) who reported a quadratic relationship existed between milk fat% and MUN concentration, with higher MUN occurring at mid-range fat percentages.

3.6. Total solids (TS) and solids non-fat (SNF)

In the current study, the overall mean of TS and NSF contents of milk were 13.79 and 9.11%, respectively. The TS and NSF contents of milk were not significantly affected by seasons. The total solids percent were 113.99±0.10, 13.65±0.15, and 13.73±0.11 in Wet Warm (December-March), Dry Cool (April-August), and Dry Hot (August=November), respectively. The solids non-fat percent were 9.14±0.04, 9.03±0.07, and 9.18±0.05 in Wet Warm (December-March), Dry Cool (April-August), and Dry Hot (August=November), respectively. The total solids percent was lowest in Dry Cool (April-August) (13.65±0.15) and reached a maximum in Wet Warm (December-March) of 13.99 ±0.10mg/dl. Solids non-fat percent were lowest in Dry Cool (April-August) (9.03±0.07), and start rising through in Wet Warm-season with the highest value recorded in Dry Hot (August- November). Despite being non-significant total solids were highest when protein and fat were also highest, however solid nonfat did not follow the same trend. Solids non-fat were highest when protein and fat were at their lowest level.

The TS (13.79%) was higher than those reported by Bille et al. (2009); Mirzadeh et al. (2010); Teklemichael (2012) of 12.33% in Namibia, 12.57% Lordgan region in Iran, and 12.58% in Dire Dawa area, respectively. The European Union subscribed to a recommended quality for TS component of cow's milk of not less than 12.5% (O'Connor, 1995). Therefore, the average TS content of milk in the current study was slightly higher than the recommended standard by the EU. The difference between our results and other findings could be explained by lactation stage, parity, and farms conditions. Also, O'Connor (1994) perceived the differences in feeding and management practices in different studies influencing variation in milk composition quality (O'Connor, 1994).

The SNF (9.1%) was higher than those reported by Desyibelew and Wondifraw (2019) of 7.47 and 8.08% for winter and summer in Zebu × HF Crossbred Dairy Cows in Ethiopia. The European Union subscribed to a recommended quality for SNF component of cow's milk of not less than 8.95% (Tamime, 2009). Therefore, the average SNF content of milk in the current study was slightly higher than the recommended standard by the EU. The possible explanation of the difference between our results and other findings is herd dynamics in terms of feeding practices, season, milking method and lactation period applied. The present study revealed the non-significant effect of season on SNF content of milk Ibeawuchi (1985) and Saxsena et al. (1997) also found a similar result.

4. Conclusion

- Conclusively, the fat, protein lactose, and milk urea nitrogen contents of milk significantly varied with the season.
- Synchronous changes in milk protein and fat are much more noticeable as the transition progresses through the dry and wet season which is an indication of the influence of dietary changes.
- Fat percent showed a positive correlation with the protein percent and total solid and vise-versa
- The ratio of protein to fat was comparatively high indicating a sign of high milk protein in cow's milk produced in Zimbabwe.
- The average MUN (14 mg/dl) is a sign of appropriate dietary protein (especially soluble protein) supply accompanied by recommended proportion and sources of nonstructural carbohydrates.

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