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Effect of feed supply on milk yield and lipid composition in Algerian dairy cows

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Abstract

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This study aims to compare the yield and lipid composition of milk in dairy cows depending on the nature of distributed feed supply as concentrate. The impact of feed supply was evaluated by introduction of maize and soya meal (C1), brewer's spent grains (C2) and distiller's dried grains with solubles (C3) into feed regime of Holstein and Montbeliarde dairy cows. Seventy-two Holstein and Montbeliarde dairy cows were followed, in real farming conditions, for a period of 14 weeks. The introduction of cereals stimulated milk production and induced a significant change in its fatty acid composition. C2 and C3 diets showed a rise in unsaturated fatty acids in milk regardless of the cow breed, while diet C1 had no significant effect on milk fat composition. The incorporation of concentrate with higher lipid content in the diet of dairy cows increases milk production and modifies milk fat quality.

Keywords: dairy cows; feed supply; concentrate feed; milk production; fatty acids

Abbreviations: BC: Butyric content; BSG: brewer's spent grain; C1: concentrate 1 (maize and soya meal); C2: concentrate 2 (brewer's spent grains); C3: concentrate 3 (distiller's dried grains with solubles); DDGS: distiller's dried grains with solubles; DDE: degreased dry extract; FAs: fatty acids; SFAs: soluble fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids; UFAs: unsaturated fatty acids; H: Holstein; M: Montbeliarde; PC: protein content, TDE: total dried extract; TF: total fat

Introduction

In order to improve the quality and quantity of milk, animal feeds have become an unavoidable factor in the intensification of animal production. This feeding of dairy cattle has a predominant influence on the quantitative as well as

qualitative production of milk intended for industrial uses. To date, concerns about productivity and biological effectiveness of the processing of raw materials into marketed animal products have become important. Also, interest in the quality of the products is of considerable importance today.

In this context, numerous works have studied the impact

of the rations of dairy cows concentrate feed based on cereal or oil crop seeds on milk yield (Petit and Alary, 1999; Andrade and Schmidely, 2006; Dos Santos et al., 2011, Bernard et al., 2016). Other studies have focused on the effect of lipid feed in ruminant feeding and its impact on the quality of the cheese produced from the milk obtained (Sanz-Sampelayo et al., 2002; Inglingstad et al., 2016). Recently, distiller's dried grains with solubles (DDGS), by-products from the alcohol industries (beer and bioethanol), have been usually sold as a high protein livestock feed and are used to feed ruminants. The rapid adoption of these raw materials is a challenge for the animal feed industry (Cozannet et al., 2010). However, the use of residues from the processing of raw plant materials for animal feed and its effect on milk quality are poorly documented in the literature.

Algeria has large amounts of crop and agro-industrial residues whose optimal use could reduce dairy cow feed costs. These include brewer's spent grain (BSG), a most important by-product of the brewing industry which represents 85% of the total by-products.

In this context, barely spent grain was used in this work as a feed supplement in the feed concentrate of two cow breeds, Holstein (H) and Montbeliarde (M). The effect of the nature of the concentrate was investigated with intensive farming conditions in a famed Algerian cow farm. The experimental period was 14 weeks. This study aims to compare the production and lipid composition of milk from different dairy cow feed diets containing corn and soybean grain meal (C1), brewer's grain (C2) or corn distiller's grains with solubles (C3) at a concentration of 30% in the feed concentrate.

Materials and Methods

Choice of livestock

In the absence of an experimental farm, the incorporation of concentrated feed C1, C2 and C3 in the diet was considered under actual farming conditions prevailing in the selected farm in Beni Mapuche (36° 30' North and 4° 47' East), located near Bejaia (200 km east of Algiers, Algeria). A sufficient number of Holstein (H) and Montbeliarde (M) dairy cows (72 cows) were selected for this study: 36 cows of each breed distributed in three batches corresponding to the three diets.

Distribution and composition of feed concentrate

The three batches of cows received the same basic diet consisting of hay and straw (Tables 1 and 2). A quantity of 10 kg hay/day/cow was distributed in two doses (5 kg in the morning, 5 kg in the evening) while 6 kg straw/day/cow was distributed in one in the evening. This basal diet was supple-

mented by 12 kg/day/cow of feed concentrate (C1, C2 or C3), distributed twice a day (5 kg in the morning, 7 kg in the evening). The distribution level of concentrated feed (12 kg/day/cow) seems acceptable, given the profile of animal experimentation set (age and weight).

Table 1. Feed concentrates composition (%)

	C1	C2	C3
Maize / grains	50	20	36
Barley / grains	0	20	0
Soya oil cake	25	5	9
Bran	22	22	22
Minerals, vitamins	3	3	3
Brewers grains	0	30	0
Distillers grains	0	0	30
Total	100	100	100

Table 2. Results of overall analysis of the feed concentrate composition (%)

Sam- ples	Humidity	Proteins	Fat	Starch	Calcium	Phos- phorus
C1	11.68	20.50	5.04	36.82	0.72	0.78
C2	11.45	20.16	5.31	28.91	0.70	0.76
C3	11.95	20.87	6.76	29.32	0.73	0.78

C: Concentrate

The corn distiller's grains used in the test were provided by the U.S. Grains Council and were stored in a suitable hangar at the farm level. They were kept in the open air in the warehouse for ventilation and to avoid fermentation to keep their characteristics.

The brewer's grains used in our experiments were provided by the Star Brewery of Algeria (B.S.A.), located in the industrial area of El-Kseur Wilaya in Bejaia (east Algeria). Grain was supplied each week to prevent deterioration by the phenomenon of fermentation due to the high instability of this food. The livestock was watered three to four times a day.

Monitoring of milk production

The work included tracking the overall and daily milk production for 14 weeks, from the morning and evening milking (morning at 7 am and evening at 5 pm) for all cows.

Sampling and analysis

Samples were taken each week from individual milks of the three batches (C1, C2 and C3), from the morning milking. The samples were collected in clean 1 L containers and stored directly at 4°C. They were labeled for their identification (sampling date, cow number) and transported to the laboratory where they were the subject of a series of analyzes.

The total dry extract (TDE) was determined by desiccation in the presence of an infrared humidity analyzer. Total protein (TP) was obtained after measuring the total amount of nitrogen following Kjeldahl digestion (AFNOR, 1986), while total fat (TF) was measured using the Gerber method (AFNOR, 1986). The conversion factor (0.945) allowed us to deduce the proportion of fatty acids (FAs) in milk fatty material (Paul and Southgate, 1978).

The lipids of different samples were extracted according to the method developed by Luna et al. (2005). These extracts were used for determination of FA composition using GC. This determination was based on the solubility of FAs in tertbutylmethyl ether (TBME; ME0552, Scharlau) and their transformation into fatty acid methyl esters (FAME; norm ISO 5509, 1990). A GHP filter of 0.45 µm diameter was used to filter samples of 2 mL each. Fifty microliters of 0.2 M trimethylsulfonium hydroxide in methanol (Macherey-Nagel) was added to 100 µL of the filtrate (Merah et al., 2012; Roche et al., 2016). From this mix, 1 µL was used for injection into a GC-3800 chromatograph (Varian) with an FID detector. The GC was equipped with a CP Select CB 50 m capillary column (0.25 mm diameter). The initial temperature was held at 185°C for 40 min, augmented at a rate of 15°C/min to reach 250°C and then held there for 10 min. The injector and detector temperatures were maintained at 250°C and 300°C, respectively. The FAME concentrations were determined by comparison with the retention times of a known standard FAME mixture (FAME rapeseed oil reference mix, Supelco, USA), used as an external standard.

Statistical analysis

All data were statistically analyzed. The standard variance was obtained with an ANOVA I criterion, using Statistica® version 6.1 (StatSoft, France). If ANOVA results were significant, Duncan’s test was utilized to compare average means. For this comparison, only one significant figure of 5% was retained.

Results and Discussion

Changing the feed concentrate appears to influence the milk production level (Table 3). Consequently, through the

Table 3. Average of milk production in dairy cows (liter per day) at the end of the experimental period, depending on the nature of the concentrate

Race	Concentrate feed			P
	C1	C2	C3	
Holstein	32.00 ± 1.15	34.97 ± 1.98	36.17 ± 1.83	***
Montbeliarde	20.10 ± 2.43	20.87 ± 1.85	21.56 ± 1.94	**

P: Statistic probability; ***: P < 0,001 ; **: P < 0,01; C: Concentrate

14 week experiment, the introduction of DDGS (distiller’s and brewer’s) induced an improved milk production, higher in batches C3 and C2 than in batch C1, whatever the cow breed (Table 3). Otherwise, as expected, Holsteins produced more milk than Montbeliarde cows (Table 3).

Moreover, the evolution of milk production curves in the 14 week experiment was plotted for each experimental group (Figure 1). There was a difference in the level of production between the two cow breeds (Figure 1). This output gap between the two breeds seems to have greater potential for initial production for Holstein cows. The same increasing trend was found for the three batches (C1, C2 and C3) but at different levels of production. This result can be explained by the growth performance of the cows (age, weight) with time. According to Fournier (2008), distiller’s grains can replace a significant portion of corn and protein supplement used in the diet of cows, which reduces the level of starch and non-structural sugars. These two factors, in addition to the high fiber content of DDGS, help to reduce the incidence of rumen acidosis.

In addition, it is interesting to note that throughout the experimental period, the C3 concentrate was more effective in terms of milk production compared to the other two concentrates (C1 and C2) for both cow breeds studied. This efficiency increased with the production potential of cows.

However, a previous study compared the milk production in dairy cows fed a diet containing corn distiller’s grains with

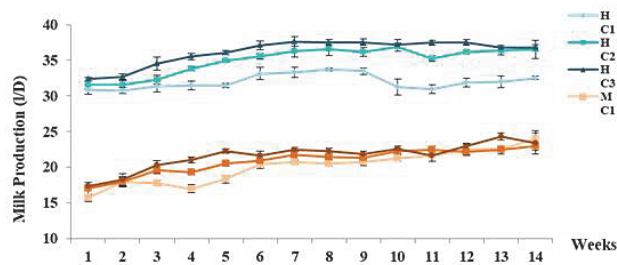


Fig. 1. Evolution of the average milk production per cow depending on the nature of the concentrate for Holstein and Montbeliarde cows

solubles or triticale distiller's grains with solubles at a concentration of 21% of the dietary dry product (Greter et al., 2008). No significant differences between sources of distiller's grains with solubles in terms of milk production or milk composition were observed, although the concentrations of blood, urea, nitrogen and some amino acids were higher with corn distiller's grains with solubles. Triticale distiller's grains with solubles can, unlike brewer's grains, replace corn distiller's grains with solubles in the diet of lactating cows, without any negative impact on milk production.

The intake of grains (C2 and C3) did not significantly vary the pH and degraded dry extract (DDE) of milk from the two breeds, Holstein and Montbeliarde (Table 4). The pH is always compliant with values ranging from 6.6 to 6.8, as already reported (Alais, 1984). Conversely, the results presented in Table 3 indicate that there was a highly significant difference of TDE only in the Holstein breed between batches C1, C2 and C3 (Table 5). It increased with the addition of DDGS. It appears that only the TDE of batch C1 was significantly different from the other batches (Table 5). According to Croguennec et al. (2008), the increase or decrease of TDE is directly related to the particular variation of total protein and fat.

The effect of the concentrate on the protein content was not significant. Despite this, there was a difference between the three batches C1, C2 and C3 (Table 4). The nature of the energy effect on the protein content is the subject of conflicting results, even if we admit that diets high in starch generally lead to an increase in protein content, at least in extreme cases (Sutton, 1989). Furthermore, the concentrated feeds C2 and C3 led to a significantly higher butterfat rate than that obtained by C1 concentrate (Table 4) whatever the cow breed.

The fat content is a relatively variable standard from one

day to another, because it is strongly linked to trade. Its level ranges from 1% to 10% between the beginning and end of the trade. However, it is one of the milk solid elements that is most strongly and quickly changed by nutrition (Holden and Coulon, 1980). According to Rulquin et al. (2007), responses of the fat content to a glucose supplement (digestible starch similar to glucose) are always negative and fat percentage decreases significantly. The role of glucose when the cereal is maize concentrate is more important (Sutton et al., 1980), then, it could explain a drop in fat content (Rulquin et al., 2007). The proportion of rich corn starch was much higher in food concentrate C1 compared to C2 and C3, which could be responsible for the significant drop in fat content in the batch (C1). However, previous studies found very interesting variations in the concentration of certain compounds synthesized by the animal, depending on its power (Bugaud et al., 2001), which could also help to explain some of the differences observed, particularly the composition of the milk fat in FAs (length of the carbon chain and degree of unsaturation), highly dependent on the feed (Joy et al., 2014; Bernard et al., 2016; Inglingstad et al., 2016). These results have directed us to analyze the milk fats by GC in order to explain the rise in fat and FA content recorded after the introduction of grains. On the other hand, milk FAs, which are highly variable with livestock feed in the short term, are an important component of its nutritional quality for humans (Maltz et al., 2013).

The FA profile of the milk fat was strongly modified by concentrated feed (Table 5). Compared to batch C1, the milk of batches C2 and C3 had reduced saturated FA content of 1.35% and 1.78%, respectively. This reduction occurred at the expense of increased, albeit statistically insignificant, unsaturated FA content. In contrast, a significant increase of linoleic acid was observed for both C2 and C3 batches, whatever the cow breed (Table 5). Moreover, batches C2 and

Table 4. Results of various milk parameters, depending on the nature of the concentrate for Holstein and Montbeliarde breeds

Race	Holstein			Montbeliarde		
	C1	C2	C3	C1	C2	C3
Feed concentrate						
pH	6.68±0.08	6.65±0.07	6.83±0.40	6.68±0.07	6.63±0.05	6.63±0.05
Acidity (°D)	16.10±0.55	16.93±0.99	16.67±0.58	15.50±0.94	16.50±0.84	16.33±0.58
Density	1.031±0.000 ^{ab}	1.032±0.001 ^a	1.030±0.000 ^b	1.030±0.001	1.031±0.001	1.031±0.000
TDE (g/l)	116.05±5.02 ^b	124.54±2.81 ^a	121.93±3.90 ^a	121.63±9.30	129.46±2.73	128.23±1.14
DDE (g/l)	83.47±4.21	85.80±3.29	80.72±3.99	86.42±6.21	90.65±2.97	87.80±0.98
PC (g/l)	31.20±0.62	31.76±1.78	32.17±0.30	32.80±1.22	31.92±0.51	31.12±2.47
BC (g/l)	32.58±1.14 ^c	38.74±1.70 ^b	41.22±0.51 ^a	35.21±3.46 ^b	38.82±0.57 ^a	40.43±0.15 ^a
FAs (g/l)	30.79±1.08 ^c	36.61±1.61 ^b	38.95±0.48 ^a	33.27±3.27 ^b	36.66±0.52 ^a	38.21±0.14 ^a

On each line, and each race, the values (mean ± standard deviation) affected by different letters are significantly different ($P < 0.05$), Duncan test. No letter a, b and c on the same line indicates no significant difference ($P > 0.05$). The letter a corresponding to the highest average adjusted.

TDE: Total Dried Extract; DDE: Degraded Dry Extract; PC: Protein content; BC: Butyric content; FAs: Fatty Acids

Table 5. Change in fatty acid composition of milk fat according to the nature of the concentrate (%)

Fatty acids	Holstein			Montbeliarde			P
	C1	C2	C3	C1	C2	C3	
C _{4:0}	2.86 ± 0.04	2.44 ± 0.01	3.13 ± 0.03	2.79 ± 0.02	2.35 ± 0.04	2.54 ± 0.06	**
C _{6:0}	1.93 ± 0.02	1.52 ± 0.01	2.23 ± 0.02	1.92 ± 0.01	1.49 ± 0.01	1.86 ± 0.01	*
C _{8:0}	1.13 ± 0.01	1.20 ± 0.01	1.42 ± 0.01	1.13 ± 0.00	1.22 ± 0.01	1.45 ± 0.01	NS
C _{10:0}	2.34 ± 0.00	2.98 ± 0.05	3.10 ± 0.06	2.29 ± 0.01	3.02 ± 0.05	3.28 ± 0.03	*
C _{12:0}	2.73 ± 0.01	3.95 ± 0.05	3.29 ± 0.02	2.65 ± 0.08	4.05 ± 0.06	4.03 ± 0.04	*
C _{14:0}	9.59 ± 0.09	10.60 ± 0.06	11.33 ± 0.06	9.58 ± 0.04	10.45 ± 0.03	10.64 ± 0.03	NS
C _{16:0}	29.62 ± 0.21	27.60 ± 0.48	24.91 ± 0.07	29.60 ± 0.37	27.65 ± 0.54	26.06 ± 0.44	*
C _{18:0}	11.86 ± 0.41	10.75 ± 0.90	11.33 ± 0.38	11.96 ± 0.65	10.72 ± 0.67	10.55 ± 0.40	NS
Others	4.84	4.41	4.26	5.07	4.75	4.93	-
SFAs	66.89 ± 0.78	65.47 ± 0.47	65.00 ± 0.37	67.00 ± 0.16	65.71 ± 0.21	65.33 ± 0.14	NS
C _{16:1}	1.54 ± 0.07	1.60 ± 0.04	1.58 ± 0.06	1.57 ± 0.07	1.63 ± 0.05	1.59 ± 0.06	NS
C _{18:1}	25.85 ± 0.42	26.25 ± 0.61	26.65 ± 0.31	25.83 ± 0.38	25.89 ± 0.24	25.95 ± 0.43	NS
Others	2.10	2.29	2.28	1.96	2.34	2.42	-
MUFAs	29.49 ± 0.32	30.14 ± 0.48	30.51 ± 0.44	29.35 ± 0.22	29.75 ± 0.10	29.96 ± 0.40	NS
C _{18:2}	2.65 ± 0.28	3.25 ± 0.06	3.31 ± 0.11	2.68 ± 0.61	3.31 ± 0.17	3.58 ± 0.34	NS
C _{18:3}	0.96 ± 0.09	1.14 ± 0.05	1.15 ± 0.06	0.98 ± 0.13	1.12 ± 0.11	1.13 ± 0.08	*
PUFAs	3.61 ± 0.46	4.39 ± 0.02	4.46 ± 0.06	3.65 ± 0.93	4.43 ± 0.40	4.70 ± 0.52	NS
UFAAs	33.10 ± 0.78	34.53 ± 0.47	34.97 ± 0.38	33.01 ± 1.15	34.18 ± 0.37	34.67 ± 0.13	NS
ω ₆ /ω ₃	2.76	2.85	2.88	2.73	2.95	3.17	
C _{18:1} /C ₁₈	2.18	2.44	2.35	2.16	2.42	2.46	*

***; P < 0.001; **, P < 0.01; *, P < 0.05; NS: P > 0.05

SFAs: Soluble Fatty Acids; MUFAs: Monounsaturated Fatty Acids; PUFAs: Polyunsaturated Fatty Acids; UFAAs: Unsaturated Fatty Acids

C3 had higher ω₆/ω₃ and C_{18:1}/C₁₈ ratios (Table 5), due to an increase in the secretion of unsaturated FAs, offset by a decrease in the secretion of saturated FAs.

Food used to vary widely, in particular milk FAs; it should be noted here that saturated FAs, representing 66% of total milk fats, are generally recognized as atherosclerotic risk factors, including increased total cholesterol and LDL cholesterol (Plamquist et al., 1993; Chilliard et al., 2001). MUFAs (oleic acid) and PUFAs may help reduce the risk of atherosclerosis, including increasing the HDL levels (Merah et al., 2012).

Furthermore, milk FAs have two sources: the bloodstream and *de novo* synthesis in the udder. The FAs taken in or synthesized can be saturated at udder level, including FAs in the blood such as triglycerides or non-esterified FAs. FAs taken from the blood include a portion of C_{14:0} and C_{16:0} and all of the milk FAs with 18 carbons. The FA sampling rate of triglycerides by the mammary gland of cows increases with their concentration in the plasma (Akraim, 2005).

Short- and medium-chain FAs (C4 to C12) and some C14 and C16 FAs are synthesized by mammalian cells from ac-

etate which is produced by ruminal fermentation (Sauvant et al., 2006; Rulquin et al., 2007). In addition, PUFAs are not synthesized by ruminants; their concentration in milk depends essentially on input from the diet (Gulati et al., 1999). One of these PUFAs is linoleic acid (C_{18:2}) which is the most represented. Its concentration was higher in the milk of batches C2 and C3 than in the milk of batch C1 (Table 5). This is probably a result of the high content of fat grains rich in PUFAs (almost 15% of dry matter) which is in line with results observed previously (Andrade and Schmidely, 2006; Bernard et al., 2016; Inglingstad et al., 2016). Further research is needed to confirm these trends.

Furthermore, the grains increased the linoleic acid content of the milk (p < 0.01) more strongly than that of acids C_{18:1} and C_{18:3}. The linoleic acid content in milk FAs is generally between 2% and 3%. While rations are enriched with seeds or oils rich in linoleic acid, this percentage does not exceed 3-4%; increases compared to the control diet are rarely greater than 1.5%. It is therefore clear that increased hydrogenation of linoleic acid in the rumen strongly limits its incorporation into FAs in milk (Chilliard et al., 2001; In-

glingstad et al., 2016). In addition, an increased proportion of linoleic acid in dairy products is not in itself an objective, insofar as improving the nutritional value of these products requires an increase in the linoleic/linolenic ratio (Chilliard et al., 2001; Bernard et al., 2016). The $\omega 6/\omega 3$ ratio ($C_{18:2}/C_{18:3}$) was modified by the intake of grains, and there was an increase in the C2 and C3 batches compared to batch C1 (Table 5).

It is also desirable to increase the $C_{18:1}/C_{18}$ ratio to reduce the hardness of butter, and to improve its nutritional quality, in particular to limit atherogenic risk in humans. This report is regulated by both the respective availability of these two FAs, for the activity of mammary desaturase, and the factors that modulate the activity (availability of PUFAs) (Chilliard et al., 2001; Andrade and Schmidely, 2006; Bernard et al., 2016).

Meanwhile, the $C_{18:1}/C_{18}$ ratio was increased in batches C2 and C3 compared to batch C1, 2.43 and 2.40, respectively, suggesting increased activity of delta-9 desaturase which converts stearic acid to oleic acid (Baumgard et al., 2001).

BSG and DDGS are potential sources of energy and protein for dairy cows. Their use would reduce the large amounts of grain and oilseed meal that some countries are forced to import to meet the needs of their livestock. To this end, and in comparison with concentrated feed containing corn and soybean meal, the introduction of grains (brewery and distillery) does not influence the normal production trends over time but rather influences the amount produced by driving a greater improvement with distiller's grains. This favorable effect on milk production was more pronounced in the early part of the experimentation period, the highest production levels achieved by cows of the Holstein breed.

Moreover, the introduction of DDGS into the diet of dairy cows was also accompanied by very significant changes in the total solids, fat and FA content.

The FA profile of milk was strongly influenced by diet. Compared to batch C1, batches C2 and C3 had reduced levels of saturated FAs, known as atherosclerosis risk factors for humans, and higher levels of unsaturated FAs, especially linoleic acid which improves the nutritional quality of milk. These are not synthesized by ruminant tissues, so that their concentration in the milk is highly dependent on food intake, primarily related to the proportion of fat provided by the grains. These PUFAs at high concentrations inhibit the *de novo* lipogenesis of saturated FAs in the mammary cells.

Conclusions

Concentrates are potential sources of energy and protein for dairy cows. They have influenced positively both milk

production and fatty acid composition regardless of the cow breed.

Moreover, the introduction of concentrates in the diet of dairy cows was accompanied also by very significant changes in the total solids content, the fat content and the fatty acid, which improves nutritional quality of milk.

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