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Effects of Milk Replacer Supplementation with Conjugated Linoleic Acid and Live Weight at Slaughter on Growth and Carcass and Meat Quality of Kids

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Abstract: The objective of present research was to determine effects of Conjugated Linoleic Acid (CLA) inclusion in milk replacer on artificial rearing of kids. CLA was fed to newborn kids as 1.2% of the diet. A commercial CLA preparation (CLA 60) containing 60% CLA isomers was included at 2% to provide 1.2% CLA in the diet. The inclusion of CLA in diet was initiated at 2 days of life and fed until slaughter. Growth, carcass and meat quality data were collected and analyzed. Treatment groups included two control diets, one slaughtered at 6 kg (C6) Live Weight al Slaughter (LWS) and another one slaughtered at 10 kg LWS (C10) and 2 CLA supplementation at 1.2% of the diet for 6 (CLA6) and 10 (CLA10) kg LWS. Average Daily Gain (ADG) was significantly ($p<0.05$) affected by the inclusion of CLA in the milk replacer. CLA 1.2%+milk replacer fed kids grew at 156 g d^{-1} while CLA 0%+milk replacer kids grew at 130.98 g d^{-1}. Commercial Carcass Yield (CCY) and Net Carcass Yield (NCY) were affected by CLA, where kids CLA fed (CLA6 and CLA 10) presented lower CCY and NCY than control kids. The statistical differences were slightly higher rising to $p<0.05$ in CCY and lower in NCY. An increase in LWS had a statistical effect on CCY and NCY, because older kids presented higher carcass yield values. A statistical interaction was observed in CCY and NCY parameters between two fixed effects, however C6 and CLA6 kids presented more differences in carcass yield than C10 and CLA10. These results may suggest a relationship between CLA feed and early abomasum development, however the empty gastro-intestinal tract was heavier in CLA6 and CLA10 than in control kids ($p = 0.03$). CLA in milk replacer tends to increase the total fat in the shoulder cut ($p = 0.073$) but no other effects are shown. There were significant differences among LWS for the percentage contribution, increasing subcutaneous and intermuscular fat, total fat and muscle and decreasing bone to carcass side weight. pH values were statistically affected by CLA inclusion in the milk replacer, but a high interaction between CLA and LWS was observed in pH_u. Initial and final pH in the Longisimus toracis et lumborum and semimembranosus muscles was higher in CLA6 than C6 but these differences did not show in 10 kg LWS kids. The L, Croma and Hue values were unaffected by CLA addition in milk replacer. The L and Hue value was slightly higher in C6 than in CLA6 for the Longissimus toracis et lumborum and Semimembranosus muscles.

Key words: CLA, kid, growth, carcass, meat, quality

INTRODUCTION

Altering fatty acid composition of ruminant muscle and adipose tissue may improve the animal's performance and the nutritional value of these food products. One approach to improving the growth of kids, feed intake and carcass and meat quality is the supplementation of naturally occurring feed additives, such as Conjugated Linoleic Acid (CLA). Conjugated linoleic acid consists of positional and geometric isomers of linoleic acid, which contain conjugated double-bond systems. The c-9, t-11 isomer was thought to be the biologically active form of CLA because it was the only isomer found in the phospholipid portion of tissue (Ha *et al*., 1990). Conjugated linoleic acid has been shown to improve growth rates of rats and act as an anticarcinogenic compound. More recently, Park *et al*. (1999) reported increased muscle and decreased fat in rats fed the t-10, c-12 isomer. Fat supplemented diets either increased (Brandt and Anderson, 1990; Bock *et al*., 1991) or did not change (Andrae *et al*., 1998) backfat thickness and the percentage of kidney, pelvic and heart fat in steers, but enhanced the percentage of fat in the carcass in bulls (Boucque *et al*., 1990) and lipid content in subcutaneous

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adipose tissue in lambs (Mir *et al*., 2000). Different responses to CLA or fat supplemented diets were probably related to the amount and type of fat and age and species of animals. No data for comparison, however, are available for kids. It has been established that dietary linoleic acid reduced abdominal fat deposition and lowered activities of some lipogenic enzymes (Sanz *et al*., 2000). CLA was found to lower fat mass by reducing cell size (Axain *et al*., 2000). The hypothesis tested in this study was how a commercial CLA preparation (CLA 60) at a constant level (1.2%) in the milk replacer diet fed for 2 different live weight at slaughter would improve growth, decrease fat depots, increase carcass yield and increase meat color. Thus, our objective was to determine the effects of CLA milk replacer feed on growth and carcass and meat quality at two different Live Weights at Slaughter (LWS).

MATERIALS AND METHODS

Animals: This project was carried out in accordance with Las Palmas de Gran Canaria University Animal Care and Use Committee guidelines. CLA-60 at 0 or 2% of the diet and kids with live weight at slaughter of 6 and 10 kg were used in a 2×2 factorial arrangement in four randomized complete blocks, each block consisting of 10 male kids (Canary Caprine Group breed). Kids were housed in a total confinement, sawdust-floor facility in four pens (3×3 m). Treatment groups included two control diets, one slaughtered at 6 kg LWS (C6) and another 1 slaughtered at 10 kg LWS (C10) and 2 CLA supplementation at 1.2% of the diet for 6 (CLA6) and 10 (CLA10) kg LWS. A commercial CLA preparation, CLA 60 (Grunau Gmbh, Illertissen, Germany; an oil containing 60% CLA isomers) was included at 2% to provide 1.2% of supplemental CLA. Kids were fed colostrum during the first 2 days of life according to Argüello (2000). After that, milk replacer (see composition in Table 1) was fed twice daily until slaughter. Kids were weighed every fortnight.

Carcass and meat procedures: Kids were weighed after fasting for 12 h with free access to water. The dressed carcass comprised the body after removing the skin, head (at the occipito-atlantal joint), fore feet (at the Carpal-metacarpal joint), hind feet (at the tarsal-metatarsal joint) and the viscera. Kidneys, kidney and pelvic fat were retained in carcass and testes and scrotal fat were also removed (in accordance with Colomer-Rocher *et al*., 1987). Hot Carcass Weight (HCW) and weights of the head, skin and some visceral organs (heart, liver, lungs plus trachea, kidney, spleen) were recorded. The gastro-intestinal tract was also weighed full and empty. The results were expressed as percentage of live weight at slaughter. Empty Body Weight (EBW) was calculated by deducting the weight of digesta. Dressing percentage was calculated based on full live weight (Commercial Carcass Yield, CCY) and EBW (Net Carcass Yield, NCY).

Table 1: Chemical analysis of milk replacer offered to the kids during the experimental period

As fed	Milk replacer	Milk replacer+CLA-60
Dry matter (%)	95.5	95.5
Ash (%)	8.0	8.0
Crude protein (%)	23.6	23.6
Crude fiber (%)	0.1	0.1
Ether extract (%)	22.7	24.7
CLA-60 (%)	0.0	2.0
Mj ME kg^{-1}	19.45	19.85

After chilling the carcasses for 24 h at 4°C, Cold Carcass Weight (CCW) was recorded. After chilling, the carcasses were split down the dorsal midline. The left side was divided into 5 primal cuts (neck, flank, ribs, shoulder and long leg) and three minor cuts (kidney, kidney fat and tail) as described by Colomer-Rocher *et al*. (1987). After weighing, shoulder was separated into dissectible muscle, bone and fat, with the subcutaneous and intermuscular fat depots being recorded separately in accordance with Argüello *et al*. (2001).

Muscle pH was determined using a Crisson 507 pH meter with a combined electrode, by insertion into the longissimus toracis et lumborum (at the 12/13th rib site) and semimembranosus (central portion) muscle, immediately after slaughter and after chilling (24 h). Muscle color was measured at the same sites, using a Minolta CR200 Chroma-meter (where L* depicts relative lightness, a* indicates relative redness and b* represents relative yellowness). Hue and Croma were calculated using a* and b* values according to Wyszecki and Stiles (1982).

Statistical analysis: Growth statistical analysis was performed with the linear regression procedure of SPSS (SPSS Inc., IL, USA). Least squares regression slopes were compared using (Martin and Luna, 1994):

$$t_{exp} = |b_i - b_j|/[S^2_D\{(1/(xx)_i)+(1/(xx)_j)\}]^{1/2}$$

Where, b_i and b_j are the slopes of the treatments i-eth and j-eth, respectively, S^2_D is the average variance and $(xx)_i$ and $(xx)_j$ are the square sums of the treatments i-eth and j-eth, respectively. Carcass and meat data were analyzed as a randomized complete block design using the GLM procedure of SPSS. The randomized complete block statistical model included fixed effects of CLA inclusion and weight at slaughter.

RESULTS AND DISCUSSION

Growth: Average Daily Gains (ADG) were significantly ($p<0.05$) affected by CLA inclusion in the milk replacer (Fig. 1). CLA 1.2%+milk replacer fed kids grew at 156 g d^{-1} while CLA 0%+milk replacer grew at 130.98 g d^{-1}. O'Quinn *et al*. (2000), Weber *et al*. (2001) and Wiegand *et al*. (2001) did not find differences in ADG between pigs fed with CLA and those not fed it, indeed Szymczyk *et al*. (2001) observed that body weight gains of broiler chickens were significantly reduced, particularly at the 1.5% dietary CLA level. Although rats fed CLA responded by significantly improved body mass gains, however this effects was observed only with the 1.0% CLA-supplemented diet (Szymczyk *et al*., 2000) or pigs born to and reared by the sow fed CLA had greater ADG then pigs reared by sows fed linoleic acid as supplementary to the diet (Bee, 2000). The experimental design of this study did not allow us to include isoenergetic diets. However, because energetic value of CLA+ milk replacer is not as high as milk replacer, we consider the results should not be confused by not including isoenergetic diets. Additionally, the concept of CLA as a nutrient with growth-promoting effects might be supported by the observation that CLA had insulin-sensitizing effects in Zucker rats (Houseknecht *et al*., 1998).

Carcass traits: Table 2 shows results of kid's performance and carcass traits. Weight parameters (LWS, EBW, HCW, CCW) were highly affected by weight at slaughter, no statistical effects of CLA milk replacer inclusion were found. On the contrary, CCY and NCY were affected by CLA, where kids fed CLA (CLA6 and CLA 10) presented lower CCY and NCY than control kids. The statistical differences were slightly higher going to 0.05 in CCY and lower in NCY. An increase in LWS had a statistical effect on CCY and NCY, because older kids presented higher carcass yield values (Warmington and Kirton, 1990). A statistical interaction was observed in CCY and NCY parameters between two fixed effects, however C6 and CLA6 kids presented more differences in carcass yield than C10 and CLA10. These results may suggest a relationship between CLA feed and early abomasum development, however empty gastro-intestinal tract were heavier in CLA6 and CLA10 than control kids. No information is given about CLA effects on carcass yield in young ruminants but Szymczyk *et al*. (2001) did not observe effects of CLA diet inclusion in broiler chickens dressing percentage. CCY and NCY of control kids ranged from 46-50%, which coincides with the results of López (1990) and Potchoiba *et al*. (1990). Chilling losses noted in the present study were similar to the previous results of López (1990) using the same breed.

Non carcass trait results are shown in Table 3. CLA inclusion statistically affects empty gastro-intestinal tract as previously related. No other effects of CLA in milk replacer were checked. The percentage contribution of the fore feet and head to LWS significantly decreased as LWS increased. Percentage contributions of various visceral organs, the head and fore feet reported in the present study were similar to those reported for different breeds at similar live weights (López, 1990; Johnson *et al*., 1995). Decreases in percentages of head and fore feet with increasing age reported in the present study, were

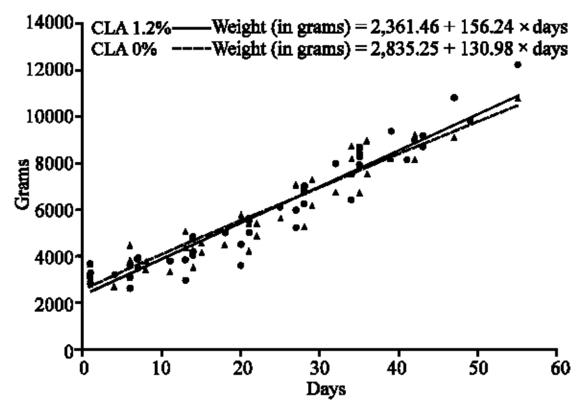

Fig. 1: Weight evolution trough experiment from control (CLA 1.2%, ●) and CLA (CLA 0%, ▲)

Table 2: Effects of Conjugated Linoleic Acid (CLA) in milk replacer on kid's performance and carcass traits

	C6	C10	CLA6	CLA10	P-value D	P-value W	P-value D×W
LWS (g)	6.062±605	10.469±1038	6.285±223	10.318±1433	NS	0.001	NS
EBW (g)	5.476±361	9.703±1065	5.499±459	9.509±1475	NS	0.001	NS
HCW (g)	2.815±242	4.978±446	2.728±154	4.985±751	NS	0.001	NS
CCW (g)	2.724±260	4.829±450	2.637±139	4.830±750	NS	0.001	NS
CL (%)	3.29±1.99	3.00±0.92	3.34±1.24	3.16±0.81	NS	NS	NS
CCY (%)	46.50±1.72	47.58±1.28	43.40±1.64	48.28±2.13	0.09	0.001	0.01
NCY (%)	49.62±1.24	50.82±2.40	46.32±1.72	50.79±0.91	0.03	0.001	0.02

LWS: Live Weight at Slaughter. EBW: Empty Body Weight. HCW: Hot Carcass Weight. CCW: Cold Carcass Weight. CL: Chilling Losses. CCY: Commercial Carcass Yield. NCY: Net Carcass Yield. CLA: Conjugated Linoleic Acid. D: Diet effect. W: Weight at slaughter effect. D×W: Effects interaction. NS: Non Statistic differences

Table 3: Effects of Conjugated Linoleic Acid (CLA) in milk replacer on non-carcass traits

					P-value		
(% on LWS)	C6	C10	CLA6	CLA10	D	W	D×W
Skin	9.32±3.48	10.22±0.89	10.23±0.80	10.09±1.35	NS	NS	NS
Fore feet	4.06±0.36	3.35±0.19	3.78±0.22	3.35±0.31	NS	0.001	NS
Full gastro-intestinal tract	16.84±4.53	16.62±4.17	18.44±3.37	16.56±3.92	NS	NS	NS
Empty gastro-intestinal tract	7.49±1.34	7.93±0.72	9.02±0.69	8.62±0.81	0.03	NS	NS
Gastro-intestinal tract content	9.35±3.92	8.68±3.93	9.41±2.80	7.95±3.98	NS	NS	NS
Liver	3.04±0.55	2.74±0.19	2.91±0.15	2.89±0.26	NS	NS	NS
Spleen	0.20±0.04	0.20±0.02	0.23±0.04	0.19±0.03c	NS	NS	NS
Kidneys	0.38±0.13	0.33±0.10	0.39±0.06	0.31±0.02	NS	NS	NS
Head	9.24±0.48	7.88±0.51	9.52±0.55	7.96±0.74	NS	0.001	NS
Lungs plus trachea	1.74±0.23	1.57±0.26	1.57±0.20	2.14±1.90	NS	NS	NS
Heart	0.68±0.14	0.59±0.04	0.60±0.06	0.64±0.08	NS	NS	NS
Thymus	0.17±0.05	0.27±0.05	0.20±0.04	0.20±0.10	NS	NS	NS

LWS: Live Weight at Slaughter. CLA: Conjugated Linoleic Acid. D: Diet effect. W: Weight at slaughter effect. D×W: Effects interaction. NS: Non Statistic differences

Table 4: Effects of Conjugated Linoleic Acid (CLA) in milk replacer on shoulder tissue distribution

					P-value		
(% on shoulder weight)	C6	C10	CLA6	CLA10	D	W	D×W
Bone	34.52±2.42	29.09±2.07	35.76±3.45	29.07±2.08	NS	0.001	NS
Muscle	58.29±0.91	62.23±2.17	56.18±2.69	60.67±3.67	NS	0.001	NS
Subcutaneous fat	1.15±0.39	2.21±0.48	1.84±0.55	2.67±0.49	NS	0.031	NS
Intermuscular fat	2.38±0.96	4.22±0.82	2.60±0.62	4.62±1.03	NS	0.001	NS
Total fat	3.53±0.68	6.43±0.94	4.44±0.60	7.29±0.95	0.073	0.001	NS
Remainders	1.64±0.26	1.46±0.43	2.13±0.95	1.63±0.73	NS	NS	NS

CLA: Conjugated Linoleic Acid. D: Diet effect. W: Weight at slaughter effect. D×W: Effects interaction. NS: Non Statistic differences

previously observed by Manfredini *et al.* (1988) and López (1990). In the present study, CLA inclusion in milk replacer did not affect liver weight, but the liver weight exhibited a slight increase in the CLA-fed rats, although the difference was not significant. Lipid accumulation in the hepatocytes of CLA-fed rats was also demonstrated by electron microscopic observation (Yamasaki *et al.*, 2000).

In reference to shoulder tissue distribution, the results are shown in Table 4. CLA in milk replacer tends to increase the total fat in the shoulder ($p = 0.073$) and no other effects are shown. The total fat values in control groups are similar to those reported by Argüello (2000) for the same breed at similar LWS. Feeding CLA reduces subcutaneous fat and increases lean in total saleable pork cuts (Dugan and Aalhus, 1999). However, Carroll *et al.* (1999) and Weigand *et al.* (2001) have reported that dietary CLA supplementation in pigs increased intramuscular fat levels. A study by Dunshea *et al.* (1998) found no significant difference in intramuscular fat between control and CLA fed pigs when visual assessment was used, however when intramuscular fat level were chemically determined CLA fed pigs had lower intramuscular fat compared with the control pigs. These data are on the contrary to results reported in this experiment, where higher fat levels in CLA kids were observed. At present, the exact mechanism of CLA induced fat-to-lean repartitioning is not known. Park *et al.* (1997) indicated that it may act in rats by increasing lipolysis while reducing lipoprotein lipase activity in adipose tissue and enhancing fatty acid oxidation in both muscle and adipose tissue. The main reason for increase fat levels in the present study may be the high-energy intake in CLA animals, because the diets were not isoenergetic. There were significant differences among LWS for the percentage contribution of subcutaneous and intermuscular fat, total fat, bone and muscle to carcass side weight (Table 4). Dairy breeds of goats tend to store more fat as visceral, rather than as carcass adipose tissue (Gibb *et al.*, 1993) which explains the low values present in subcutaneous fat. Fat carcass proportions in the present experiment are in agreement with results of Treacher *et al.* (1987) and Warmington and Kirton (1990) with different goat breeds. The contribution of bone to side carcass weight was lower when LWS of kids was high. Bone deposition in animal development precedes deposition of muscle and fat, which should be the reason for these bone results (Treacher *et al.*, 1987). Percentages of bone in the carcass observed in the present study were slightly greater than found for other dairy goat breeds like Saanen (Warmington and Kirton, 1990), but coincide with those reported by López (1990) for the same breed but with different rearing techniques. 10 kg LWS kids tended to have a higher muscle content than 6 kg LWS kids, which is in contrast to the finding of Treacher *et al.* (1987) and Sanz *et al.* (1990) involving a lower muscle carcass content in weaned kids. Aggressive weaning management and post-weaning nutrition in these articles may be the reasons for these differences. López (1990) reported a similar muscle side carcass content with comparable LWS and rearing techniques.

Table 5: Effects of Conjugated Linoleic Acid (CLA) in milk replacer on muscle pH

					P-value		
	C6	C10	CLA6	CLA10	D	W	D×W
Longisimus toracis et lumborum							
pH_0	5.96±0.15	6.25±0.44	6.87±0.16	6.26±0.31	0.001	NS	0.002
pH_u	5.49±0.13	5.63±0.25	6.14±0.46	5.44±0.08	0.039	0.013	0.001
Semimembranosus							
pH_0	6.06±0.09	6.20±0.51	6.79±0.20	6.38±0.30	0.005	NS	0.069
pH_u	5.50±0.17	5.55±0.28	6.03±0.37	5.51±0.11	0.022	0.027	0.010

CLA. Conjugated Linoleic Acid. D. Diet effect. W. Weight at slaughter effect. D×W. Effects interaction. NS. Non Statistic differences

Table 6: Effects of Conjugated Linoleic Acid (CLA) in milk replacer on muscle pH

					P-value		
	C6	C10	CLA6	CLA10	D	W	D×W
Longisimus toracis et lumborum							
L_0	57.25±3.03	51.08±3.19	50.33±2.85	52.57±3.97	NS	NS	NS
$Croma_0$	10.60±1.69	10.59±2.90	9.94±0.90	9.25±2.63	NS	NS	NS
Hue_0	36.86±9.28	31.56±7.28	29.29±5.57	36.75±11.54	NS	NS	NS
L_u	59.86±2.40	57.13±3.91	55.09±2.75	58.08±3.78	NS	NS	NS
$Croma_u$	11.30±2.87	15.63±4.10	11.72±1.29	12.12±2.11	NS	0.053	NS
Hue_u	35.14±7.69	39.68±8.80	27.59±3.02	41.65±12.17	NS	NS	NS
Semimembranosus							
L_0	55.40±1.18	52.49±3.30	51.86±2.76	55.08±3.41	NS	NS	NS
$Croma_0$	7.79±1.61	10.13±1.80	9.91±2.49	8.30±2.12	NS	NS	NS
Hue_0	33.36±16.71	33.17±6.33	32.18±7.19	41.08±13.62	NS	NS	NS
L_u	59.47±2.47	56.74±2.98	55.95±2.38	57.76±3.88	NS	NS	NS
$Croma_u$	9.02±2.23	13.18±3.54	10.85±2.43	11.49±3.31	NS	0.066	NS
Hue_u	36.51±10.57	41.84±8.64	28.89±7.49	36.74±9.45	NS	NS	NS

LWS: Live Weight at Slaughter. CLA: Conjugated Linoleic Acid. D: Diet effect. W: Weight at slaughter effect. D×W. Interaction effects. NS: Non Statistical differences

pH and color meat: pH values were statistically affected for CLA inclusion in milk replacer, but a high interaction between CLA and LWS was observed in pH_u (Table 5). Initial and final pH in both muscles was higher in CLA6 than C6 but these differences did not show in 10 kg LWS kids. The use of CLA in diets has been reported to increase pH values in chicken (Lee *et al*., 1999) and pigs (D'Souza and Mullan, 2002), or not affect pH values in pigs (Dugan and Aalhus, 1999; Wiegand *et al*., 2001). The reason for the results of the present experiment is not clear, it may be a that a high energy intake in CLA kids produced a high glycogen level in muscle in 6 kg LWS kids and the metabolization of this is higher in 10 kg LWS kids producing similar pH values in C10 and CLA10. The ultimate pH range of control groups are acceptable according to Hedrick *et al*. (1994), but lower than shown by Feidt and Bellut (1996) in Alpine kids slaughter at 24 kg. The LWS difference in ultimate pH in longissimus muscle agrees with the finding of Gonzalez *et al*. (1983).

The L, Croma and Hue values were unaffected by CLA addition in milk replacer (Table 6). L and Hue value was slightly increase in C6 than in CLA6 for Longissimus toracis et lumborum and Semimembranosus muscles. Subjective scores for color were not affected by CLA in pigs (Wiegand *et al*., 2001) and L values were unaffected by CLA, however CLA-fed pigs had slightly higher Croma values (Dugan and Aalhus, 1999). Park *et al*. (2000) hypothesized that CLA inhibits myoglobin oxidation due to delayed lipid oxidation, but had only small effects on meat color.

CONCLUSION

The results of this study show that dietary supplementation of milk replacer with CLA-60 improves the ADG and fat carcass content and reduces carcass yield by an early development of the abomasum. An interesting interaction between CLA and LWS was seen in pH values. Detailed investigations concerning observed interactions and carcass yield reduction are needed as well as the incorporation of CLA in different tissues.

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