Effect of type of suckling and polyunsaturated fatty acid use on lamb production. 1. Productive performances and quanti-qualitative characteristics of the carcass

Francesco Toteda¹, Anna Maria Facciolongo², Arcangelo Vicenti², Liborio Melodia², Francesco Bozzo²

¹Dipartimento di Progettazione e Gestione dei Sistemi Agro-Zootecnici e Forestali. Università di Bari, Italy
²Dipartimento di Produzione Animale. Università di Bari, Italy

Corresponding author: Prof. Francesco Toteda. Dipartimento di Progettazione e Gestione dei Sistemi Agro-Zootecnici e Forestali. Via G. Amendola 165/A, 70126 Bari, Italy – Tel. +39 080 5442836 – Fax: +39 080 5442822 – Email: toteda@agr.uniba.it

Paper received September 16, 2003; accepted December 22, 2003

ABSTRACT

The aim of the study was to estimate the influence of artificial rearing and of the addition of polyunsaturated fatty acids (PUFA) to an acidified milk replacer on the productive performances and on the quanti-qualitative characteristics of the carcass. Fifty one twin-born Gentile di Puglia lambs were subdivided into three homogenous groups (9 females and 8 males) assigned the following feeding treatments: maternal milk (MM); acidified milk replacer (MR); acidified milk replacer + 10 ml/l of a mixture of linseed and fish oil rich in PUFA (MR+PUFA).

Milk consumptions and live weights were recorded weekly. Seven males from each group were slaughtered at 45 days of age and the net warm dressing percentage, the composition of the carcass and the colorimetric characteristics of the Longissimus lumborum muscle were estimated. Artificial rearing improved the daily weight gain (0.182-0.172 vs 0.128 Kg; P<0.01) of lambs, provided fatter carcasses and meat with a better red index (6.16-6.43 vs 8.03; P<0.01).

The addition of omega-3 fatty acids to the diet did not influence the weight gain, the feed conversion index, the net warm dressing percentage and the incidence of the different meat cuts of the half carcass. However, it significantly increased the half carcass length (37.86 vs 35.0 cm; P<0.05), the thoracic depth (19.71 vs 16.50 cm; P<0.01) while, it compared to the MR group reduced the proportion of lean (63.21 vs 53.98 %; P<0.01) in favour of bone (20.94 vs 29.40 %; P<0.01) in the lumbar region.

Key words: Suckling lambs, PUFA, Productive performances, Carcass characteristics, Meat quality.

RIASSUNTO

EFFETTO DEL TIPO DI ALLATTAMENTO E DELL’IMPIEGO DI ACIDI GRASSI POLINSATURI SULLA PRODUZIONE DELL’AGNELLO. 1. PERFORMANCE PRODUTTIVE E CARATTERISTICHE QUANTI-QUALITATIVE DELLA CARCASSA

La ricerca è stata condotta per valutare l’influenza del tipo di allattamento e dell’aggiunta di acidi grassi omega-3 al latte ricostituito sulle performance produttive e sulle caratteristiche quanti-qualitative della carcassa. Cinquantuno agnelli di razza Gentile di Puglia, provenienti da parto gemellare, sono stati suddivisi in tre loti omogenei (9 femmine e 8 maschi)
così alimentati: latte materno (MM); latte acido ricostituito (MR); latte acido ricostituito + 10 ml/l di olio plus omega-3 contenente olio di lino e olio di pesce (MR+PUFA).
Settimanalmente sono stati rilevati i consumi di latte e i pesi vivi. Su sette maschi per lotto è stata valutata la resa alla macellazione, la composizione della carcassa e sul Longissimus lumborum le caratteristiche colorimetriche. I risultati indicano che con l’allattamento artificiale si sono ottenuti migliori incrementi ponderali giornalieri (0,182-0,172 vs 0,128 Kg; P<0,01), carcasse più grasse e carni con un migliore indice del rosso (6,16 - 6,44 vs 8,03; P<0,01). L’arricchimento della dieta con acidi grassi omega-3 non influenza gli accrescimenti, gli indici di conversione alimentare, la resa alla macellazione e l’incidenza dei vari tagli della mezzena ma aumenta significativamente la lunghezza della mezzena (37,86 vs 35,00 cm; P<0,05), la profondità toracica (19,71 vs 16,50 cm; P<0,01) e nella lombata, rispetto al lotto MR, riduce l’incidenza del magro (63,21 vs 54,81%; P<0,05) a favore dell’osso (22,70 vs 29,40%; P<0,01).
Parole chiave: Agnelli, Allattamento, PUFA, Performance produttive, Caratteristiche carcassa.

Introduction

Artificial rearing in sheep and goat breeding has been object of many studies (Congiu 1986; Lanza et al., 1990; 1992; Andrighetto et al., 1993) since it offers remarkable economic advantages to the breeder, priming a production cycle based on the commercialization of milk and cheeses. Moreover, animals can be slaughtered at a higher live weight and twins (frequent due to the technique of estrus synchronization) can be reared as well as orphans or lambs of mothers with an inconsistent milk production (Verità and Cianci, 1992; Bittante et al., 1997).

It is also important that artificially reared lambs adapt more easily to the use of weaning fodders (Sevi et al., 1996) and not being in contact with the mothers they are protected from some contagious pathologies. In mutton breeding, artificial rearing reduces the interval between lambing and breeding. In addition, the use of acidified milk replacers may reduce the difficulties of practical management and elevated labour and equipment costs of this technique (Andrighetto et al., 1993; Sahlu et al., 1992; Massari et al., 1994 a, b; Pinna et al., 1994; Celi et al., 1997; Galina et al., 1996).

With regard to the influence of artificial rearing on productive performances and on quantitative and qualitative characteristics of the carcass, the results so far reported are quite controversial (Girolami et al., 1994; Sevi et al., 1996; Vergara and Callego, 1999; Napolitano et al., 2002 a, b).

Some fatty acids are essential for the human body (Stubs and Smith, 1984; Dutta-Roy, 1994) which is not able to synthesize them and unsaturated fatty acids, especially those of the omega-3 series, have positive effects on metabolic diseases (Sim, 1997; Simopoulos, 1997; Sheard, 1998; Nordoy et al., 2001), on the development and function of the retina and brain (Uauy et al., 1989; Innis 1991; Hoffman et al., 1993) and prevent prostate cancer (Norrish et al., 1999; William et al., 2001). For this reason many research projects have been carried out with the aim of producing meat and milk with a higher content of these fatty acids, from sheep (Mir et al., 2000; Kitessa et al., 2001a; 2003; Ponnampalam et al., 2001a, b, c; Velasco et al., 2001), goat (Mir et al., 1999; Kitessa et al., 2001b; Ragni et al., 2001; Vicenti et al., 2001) and pig (Van Oeckel et al., 1996). During the pre-ruminant stage of life, omega-3 fatty acids may be administered directly with the diet since they do not undergo hydrogenation at the rumen level and so pass directly into the abomasum in a similar way to monogastrics (Bernardini et al., 1997; Piva et al., 1998; Castellini et al., 1999).

In this study, we investigated the influence of the type of rearing and of the addition of polyunsaturated fatty acids to an acidified milk replacer on the productive performances and on some quantitative and qualitative characteristics of the lamb carcass.

Material and methods

The experiment was carried out in Bovino, near Foggia (Apulia, South Italy; 41° N, 600 m above the sea level). In November, 51 twin Gentile
di Puglia lambs born from sheep submitted to estrus synchronization were subdivided into three homogenous groups of 17 subjects each (9 females and 8 males) and given the following feeding treatments: maternal milk (group MM); acidified milk replacer (group MR); acidified milk replacer supplemented with 10 ml/l of a mixture of linseed and fish oil containing polyunsaturated fatty acids (group MR + PUFA).

In order to balance the fat content of the MR+PUFA diet, 10 ml/l coconut oil was added to the MR diet. Of the two twins, one was assigned to natural suckling while the other to one of the two artificial suckling groups. Artificial rearing was performed in single 0.80 m² boxes in a closed and ventilated barn where the average temperature during the trial ranged between 10 and 15° C. Lambs in the MR and MR+PUFA groups were separated from their dams two days after birth and the addition of lipids to the milk replacers began in the second week of experimentation. The milk replacer was prepared with 200 g milk powder/litre water, kept at room temperature and distributed 3 times daily in buckets equipped with teats from which lambs could suck the milk ad libitum. The residual amounts of milk were measured daily before the new distribution. In order to avoid ingestion of litter, the bedding was covered with a plastic net. During the third week of the trial, lambs were treated with sulphonamide because they were infested with coccids.

Live weights and milk consumptions were recorded weekly in order to calculate the daily weight gain and the feed conversion index. Every 10 days, samples of milk were collected from the ewes in order to assess the chemical composition. Due to health problems, two subjects in the MM group and one each in the MR and MR+PUFA groups were discarded for the statistical processing of data. At 45 days of age, after 12 hours of fasting, six male lambs in the MM group and seven in each of the MR and MR+PUFA groups were slaughtered. After refrigeration at 4° C for 24 hours, the carcasses were measured, sectioned into cuts, and the pelvic limb and the lumbar region were dissected into tissue components (lean, fat and bone) (ASPA, 1991). A spectro-photometer (Hunter Lab with D65 illuminant) was used to evaluate colorimetric parameters (L, a, b) of the Longissimus lumborum muscle.

Data were analyzed by ANOVA using the GLM procedure of SAS (1999-2000), taking into consideration only the diet effect in a mono-factorial model. Means were compared using Student’s T test.

**Results and discussion**

**Productive performances**

Since no significant differences between sexes were recorded, data have been pooled. The daily weight gain (Table 1) was significantly (P<0.01) higher following artificial rearing both in the MR and in the MR+PUFA groups (0.182 and 0.172 Kg/d, respectively) than in the MM group (0.128 Kg/d); therefore, the weight of the naturally reared lambs at the end of the trial was approximately 2 Kg less than that recorded for both artificially

---

**Table 1. In vivo performances.**

| Parameters                  | Group         | SED |
|-----------------------------|---------------|-----|
|                             | MM            | MR  | MR+ PUFA |
| Lambs n.                    | 15            | 16  | 16        |
| Initial live weight (Kg)    | 3.06          | 3.14| 3.08      |
| Final live weight (Kg)      | 8.42 B        | 10.78 A | 10.31 A   |
| Weight gain (Kg/d)          | 0.128 B       | 0.182 A | 0.172 A   |
| Dry matter consumption (Kg) | 0.130 B       | 0.253 A | 0.235 A   |
| Feed conversion index (Kg/kg)| 1.08 B       | 1.45 A | 1.39 A    |

Mean within rows bearing different superscript (A, B) differ significantly at P<0.01.
reared groups (8.42 vs 10.78-10.31 Kg; P<0.01). The moderate weight gain found in all the groups may be explained by the low environmental temperatures and the coccid infection, and also by the fact that twin delivery determined a low birth weight, which according to Peters et al. (1996) may exert a negative effect on the subsequent body weight increases.

In the MM group, a smaller weight gain was associated to a smaller daily ingestion of dry matter (0.130 vs 0.253-0.235 Kg; P<0.01) and to a better feed conversion index (1.08 vs about 1.4; P<0.01). We must take into account, however, that the milk replacers had a lower percentage of fat (4.30 vs 4.90) and protein (3.97 vs 5.53) in comparison with the dam’s milk. In this study, the conversion indexes of milk into meat are similar to those reported in other researches (Lanza et al., 1992; Casamassima et al., 1990; 1991) and more satisfactory than those reported by Andrighetto et al. (1993); this difference may be attributable to the genetic type and/or to the chemical composition of milk. The best weight increases recorded with artificial rearing are in contrast with researches in which no influence (Sevi et al., 1996; Napolitano et al., 2002a) or even a worsening effect of artificial suckling has been found (Napolitano et al., 2002b). Likewise, the differences may be due to the genetic type, to the quantitative and qualitative characteristics of the maternal milk or to the different method of administration of the milk replacer.

Furthermore, it must be considered that the ad libitum administration of milk allows more frequent and less abundant meals which may have positively affected the digestibility and ingestion of dry matter.

Slaughtering data
Lambs fed with maternal milk (Table 2) showed a lower empty body weight (8.27 Kg; P<0.05) and a greater incidence of the gastroenteric apparatus (9.80%) than the MR+PUFA group (8.24%; P<0.05) and especially the MR group (8.01%; P<0.01), and of the head (6.63 vs 5.43-5.56%; P<0.01). On the other hand, the incidence of the pluck (5.24%) and of the omentum (0.28%) was significantly lower (P<0.05) only compared with the values recorded for the MR+PUFA group. The lowest (65.70%) net warm dressing percentage was recorded in the MR+PUFA group and the highest (67.57%) in the MM one.

In general, the slaughtering yield obtained in our study was higher than the results reported for Comisana lambs (Napolitano et al., 2002a), while quite similar to Sardinian lambs (Napolitano et al., 2002b). Moreover, Sanudo et al. (1997) obtained a yield ranging between 50.3 and 55.9%, with statistical differences (P<0.05) between the genotypes in a study involving lambs of four different breeds in natural suckling and slaughtered at one month of age. In the present research, significant effects of the type of suckling were not observed on the slaughtering yield and this result

### Table 2. Slaughtering data.

| Parameters                        | MM        | MR        | MR+PUFA   | SED      |
|-----------------------------------|-----------|-----------|-----------|----------|
| Empty body weight (EBW) Kg        | 8.27 b    | 10.97 a   | 10.56 a   | 1.786    |
| Hide % EBW                       | 13.07     | 14.00     | 13.98     | 1.071    |
| Empty digestive tract %           | 9.80 Aa   | 8.01 B    | 8.24 ABb  | 1.162    |
| Omentum %                        | 0.28 b    | 0.48 ab   | 0.53 a    | 0.218    |
| Net warm dressing percentage %    | 67.57     | 67.38     | 65.70     | 2.263    |
| Chilling loss %                   | 4.09 a    | 3.28 ab   | 2.25 b    | 1.604    |
| Head %                            | 6.63 A    | 5.56 B    | 5.43 B    | 0.504    |
| Pluck %                           | 5.24 b    | 5.78 ab   | 6.32 a    | 0.759    |

*Mean within rows bearing different superscript (A, B; a, b) differ significantly at P<0.01 and P<0.05.*
is in substantial agreement with Napolitano et al. (2002a) but in contrast with the findings reported by Vergara and Gallego (1999), who found a higher yield with natural suckling, and with those of Girolami et al. (1994) and Napolitano et al. (2002b), who recorded a higher yield following artificial rearing. The differences are probably due to the different amounts of forage ingestion.

The chilling loss was higher in lambs nursed by the mothers, but this difference is pronounced only in comparison with lambs receiving PUFA (4.09 vs 2.25%; P<0.05).

Sectioning data

The half carcass weight (Table 3) was similar for the artificial suckling groups (2.78-2.95 Kg) and higher than the group fed with maternal milk (2.21 Kg), especially when compared to the MR group (P<0.05). The incidence of several cuts, except for the neck, steaks, lumbar region and pelvic limb, was statistically different between the group nursed by ewes and those receiving the milk replacers. In fact, in MM lambs a greater incidence of the shoulder (19.81 vs 18.09 - 17.76 %) and of shanks (3.92 vs 3.24-3.52 %) was found, whereas in both the artificially reared groups there was a higher incidence of chest, abdominal region, kidney fat and kidneys.

With regard to the dissecting data (Table 4), no marked differences emerged between the groups regarding the lean, bone and the fat fractions of the pelvic limb; MR lambs showed a significantly greater lean percentage for the lumbar region, in comparison with the MR+PUFA group (60.62 vs 54.81 %; P<0.05) and a smaller incidence of bone (22.70 vs 29.40-31.04 %; P<0.01). When calculating the overall amount of lean meat obtained from the two cuts, the absolute value recorded for artificially reared lambs was greater than that from lambs fed under mothers (670.3 vs 545.9 g).

Lambs fed with maternal milk and those fed the milk replacer supplemented with PUFA showed significantly higher (P<0.01) lean/bone (1.89 vs 2.74) and lean+fat/bone (2.28 - 2.43 vs 3.52) ratios in the lumbar region, in comparison with the MR group.

The percentage of lean in the pelvic limb obtained in our study was higher than the data reported by Perez et al. (2002) in Suffolk lambs but quite similar to that recorded by Ruiz de Hidobro and Caneque (1994). The differences may be attributed to the dissection technique or to the different growth rate of the muscle in the different breeds.

With reference to the pelvic limb, the lean/bone

| Table 3. Sectioning data. |
|---------------------------|
| Parameters           | MM  | MR  | MR+PUFA | SED DF = 17 |
| Half carcass weight (HCW) Kg | 2.21 b | 2.95 a | 2.78 ab | 0.527 |
| Neck % HCW | 8.84 | 8.66 | 8.36 | 1.628 |
| Shoulder | 19.81 A | 18.09 B | 17.77 B | 0.982 |
| Steaks | 15.00 | 15.37 | 15.27 | 1.724 |
| Brisket | 9.09 Bb | 10.19 AAb | 10.62 A | 0.919 |
| Loin | 7.45 | 7.05 | 8.25 | 1.305 |
| Abdominal region | 2.68 B | 4.48 A | 4.13 A | 0.611 |
| Leg | 31.74 | 30.66 | 30.07 | 1.532 |
| Kidney fat | 0.66 B | 1.30 A | 0.94 AB | 0.360 |
| Kidneys | 0.79 b | 0.96ab | 1.07 a | 0.216 |
| Shanks | 3.92 Aa | 3.24 B | 3.52 AbB | 0.273 |

Mean within rows bearing different superscript (A, B; a, b) differ significantly at P<0.01 and P<0.05.
and lean+ fat/bone ratios were more satisfactory in the MR+PUFA group, whereas the highest lean/fat ratio was found in lambs fed with maternal milk. Perez et al. (2002) found a better meat/bone ratio in Suffolk male lambs slaughtered at a similar weight, while the fat/lean ratio was approximately half the value recorded in this trial.

The higher quantity of fat in artificially suckled lambs as evidenced by the relative values of the omentum, perineal fat, abdominal region, cuts of the pelvic limb and lumbar region, may be ascribed to higher feed ingestion that may have determined a greater growth rate increase. In fact, some authors (Wan Zahari et al., 1989) have reported that a high growth rate may cause greater development of the adipose tissue while others (Rattray et al., 1973) observed that fatter carcasses have been obtained in lambs fed ad libitum.

**Carcass measurements**

With concern to carcass measurements, no differences between the groups were recorded for the length of the body and the width of the rump (Table 5); however, the depth of the thorax was significantly greater in the MR+PUFA group (19.71 cm) than in the group suckled naturally (17.71 cm; P<0.05) and the MR group (16.50 cm; P<0.01).

Table 4. Dissection data.

| Parameters         | Group SED | MM       | Group | MR       | MR + PUFA | SED | DF = 17 |
|--------------------|-----------|----------|-------|----------|-----------|-----|--------|
| Leg weight         | g         | 700 b    | 903 a | 833 ab   | 186.250   |     |        |
| Lean % leg weight  |           | 64.40    | 63.29 | 62.19    | 3.874     |     |        |
| Fat "              |           | 7.35     | 9.51  | 8.25     | 2.972     |     |        |
| Bone "             |           | 28.24    | 27.20 | 29.56    | 2.665     |     |        |
| Lean /bone (on leg)|           | 2.32     | 2.34  | 2.12     | 0.307     |     |        |
| Lean + fat /bone (on leg)|       | 2.58     | 2.69  | 2.40     | 0.322     |     |        |
| Lean /fat (on leg) |           | 10.41    | 6.90  | 9.74     | 5.065     |     |        |
| Loin weight        | g         | 166 b    | 207 ab| 229 a    | 52.03     |     |        |
| Lean % loin weight |           | 57.27 ab | 60.62 a| 54.81 b  | 5.32      |     |        |
| Fat "              |           | 11.68    | 16.67 | 15.78    | 4.485     |     |        |
| Bone "             |           | 31.04 A  | 22.70 B| 29.40 A  | 4.067     |     |        |
| Lean /bone (on loin)|         | 1.89 B   | 2.74 A| 1.89 B   | 0.405     |     |        |
| Lean + fat /bone (on loin)| | 2.28 B   | 3.52 A| 2.43 B   | 0.550     |     |        |
| Lean /fat (on loin)|           | 5.43     | 3.86  | 3.89     | 1.652     |     |        |

Mean within rows bearing different superscript (A, B; a, b) differ significantly at P<0.01 and P<0.05.
Table 5. Carcass measurements.

| Parameters          | Group  | SED  |
|---------------------|--------|------|
|                     | MM     | MR   | MR + PUFA | DF = 17 |
| Thorax width cm     | 11.00 b | 13.67 a | 13.00 ab | 1.868 |
| Leg length "         | 24.00 b | 26.50 a | 26.29 a | 1.893 |
| Body length "        | 45.71   | 47.00   | 47.71 | 2.436 |
| Half carcass length "| 35.57 ab | 35.00 b | 37.86 a | 2.855 |
| Thorax depth "      | 17.71 ABb | 16.50 B | 19.71 Aa | 1.788 |
| Rump width "        | 14.14   | 15.17   | 14.71 | 1.215 |

Mean within rows bearing different superscript (A, B; a, b) differ significantly at P<0.01 and P<0.05.

Table 6. Colorimetric characteristics of the meat.

| Parameters | Group  | SED  |
|------------|--------|------|
|            | MM     | MR   | MR + PUFA | DF = 17 |
| L          | 46.55  | 49.51 | 46.71 | 3.889 |
| a          | 8.03A  | 6.16B | 6.43B | 0.925 |
| b          | 11.59  | 12.40 | 12.22 | 1.129 |

Mean within rows bearing different superscript (A, B) differ significantly at P<0.01.

(1994) report that the administration of milk diets in place of solid meals does not seem to influence meat colour. Other studies report that meat colour is influenced by the genotype (Sanudo et al., 1997) as well as by the duration and temperature of meat storage (Ledward et al., 1986).

Conclusions

From the results obtained in our study, the following conclusions may be drawn:

- artificial rearing does not influence lamb viability and it positively affects the daily weight gain, probably because of a greater food availability;
- it does not influence the slaughtering yield and the proportion of the valuable cuts of the carcass;
- the higher level of fat deposition may be due to the greater growth rate of lambs.

Within the artificial suckling groups, the addition of polyunsaturated fatty acids to the acidified milk replacer does not seem to influence the live weight increase, the feed conversion index, the slaughtering yield or the other parameters taken into consideration. However, dissection of the lumbar region revealed a higher incidence of bone than of lean meat.

The authors gratefully acknowledge Mr. Massimo Lacitignola for his technical assistance.

Research funded by MURST (ex-grant 60%).

REFERENCES

Andrighetto, I., Bailoni, L., Andreoli D., 1993. Impiego di succedanei acidificati del latte nella produzione dell’agnello leggero: osservazioni preliminari e comparazione con una tecnica di allattamento naturale. Zoot. Nutr. Anim. 16: 169-175.
GALINA, M.A., HUMMEL, J., GUERRERO, M., MORALES, R., GIROLAMI, A., ZULLO, A., COLATRUGLIO, P., CAPPUCCIO, A., CONGIU, F., 1986. La produzione del capretto da latte.

CASAMASSIMA, D., CAGNETTA, P., MUSCIO, A., 1990. Effetto del fotoperiodo sulle prestazioni produttive di agnelli allattati artificialmente. Zoot. Nutr. Anim. 16: 255-261.

CASTELLINI, C., DAL BOSCO, A., BATTAGLINI, M.B., 1999. Effetto dell’integrazione alimentare di acidi gras-si polinsaturi della serie n-3 sulla composizione lipidica e sulla stabilità ossidativa della carne di coniglio. Zoot. Nutr. Anim. 25: 63-70.

CELLI, R., TOTEDA, F., DI TRANA, A., FACCIOLONGO, A.M., GAMBIACORTA, M., 1997. L’impiego dell’idrolizzato di caseinina nel’allattamento artificiale. Zoot. Nutr. Anim. 30: 679-74.

CONGIU, F., 1986. La produzione del capretto da latte in allevamento artificiale. Prove di macellazione a 35 giorni di età. Agr. Ric. 8(66): 27-38.

DUTTA-ROY, A.K., 1994. Insulin mediated processes in platelets, monocytes/macrophages and erythrocytes: effects of essential fatty acid metabolism. Prostaglandins. Leukot. Essent. Fatty Acids. 51: 385-399.

GALINA, M.A., HUMMEL, J., GUERRERO, M., MORALES, R., LOPEZ, B., 1996. Artificial rearing with milk, acid milk, cow replacer and mixture with them in the replacer. pp 396-399 in Proc. 6th Int. Conf. on Goats. Beijing, China.

GIROLAMI, A., ZULLO, A., COLATRUGLIO, P., CAPPUCCIO, A., RUBINO, R., MATASDINO, D., 1994. Comparison among Ile de France (IF), Gentille di Puglia (GP) and IF x GP (F1, F2, F3) crossbreed lambs. IV. Performances at slaughter. Prod. Anim. III Series. 7: 1-49.

HOFMANN, D.R., BIRCH, E.E., BIRCH, D.G., UAYO, R.D., 1993. Effect of supplementation with n-3 long chain polyunsaturated fatty acids on retinal and cortical development in premature infants. Amer. J. Clin. Nutr. 57 (Suppl.): 807S-812S.

INNIS, S.M., 1991. Essential fatty acids in growth and development. Prog. Lipid Res. 30: 39-103.

KITESSA, S.M., GULATI, S.K., ASHES, J.R., FLECK, E., SCOTT, T.W., NICHOLS, P.D., 2001b. Utilisation of fish oil in ruminants. II. Transfer of fish oil fatty acids into goats’ milk. Anim. Feed Sci. Technol. 90: 201-208.

KITESSA, S.M., PEAKE, D., BENCI, R., WILLIAMS, A.J., 2003. Fish oil metabolism in ruminants. III. Transfer of n-3 polyunsaturated fatty acids (PUFA) from tuna into sheep’s milk. Anim. Feed Sci. Technol. 108: 1-14.

LANZA, A., PENNINI, P., BIONDI, L., 1990. Esperienze su moderne tecniche alimentari nel settore ovicapino. Tecn. Agr. 3: 3-39.

LANZA, A., PENNINI, P., BIONDI, L., BARRESI, S., 1992. Produzione dell’agnello pesante alimentato con un sostituvo a diverse concentrazioni. Zoot. Nutr. Anim. 18: 27-34.

LEWIS, D.A., DICKSON, R.F., POWELL, V.H., SHORROSH, W.R., 1986. The colour and colour stability of beef Longissimus Dorsi and Semimembranosus muscles after effective electrical stimulation. Meat Sci. 16: 245-265.

MASSARI, M., FRESCHI, P., GAMBIACORTA, E., 1994a. Indici di efficienza produttiva in agnelli Comisani allevati con latte ricostituito acidificato. pp 165-167 in Proc. 11 th Nat. Congr. SIPAOC, Perugia, Italy.

MASSARI, M., FRESCHI, P., GAMBIACORTA, E., PANIO, E., 1994b. Impiego del latte ricostituito acidificato in agnelli Comisani: Rasse alla macellazione. pp 169-171 in Proc. 11 th Nat. Congr. SIPAOC, Perugia, Italy.

MIR, Z., RUSSHIELD, M.L., MIR, P.S., PATTERSON, L.J., WESER, R.J., 2000. Effect of dietary supplementation with either conjugated linoleic acid (CLA) or linoelc acid rich oil on the CLA content of lambs tissue. Small Ruminant Res. 36: 25-31.

MIR, Z., GOONWARDENE, L.A., OKINE, E., JARGAR, S., SCHEER, H.D., 1999. Effect of feeding canola oil on constituents, conjugated linoleic acid (CLA) and fatty acid profile in goats milk. Small Ruminant Res. 33: 137-143.

NAPOLITANO, F., BRAGHERI, A., CIFUNI, G.F., PACCELLI, C., GIROLAMI, A., 2002a. Behaviour and meat production of organically farmed unweaned lambs. Small Ruminant Res. 43: 179-184.

NAPOLITANO, F., CIFUNI, G.F., PACCELLI, C., RIVIZZI, A.M., GIROLAMI, A., 2002b. Effect of artificial rearing on lamb welfare and meat quality. Meat Sci. 60: 307-315.

NORDOY, A., MARCHIOLI, R., ARNESI, H., VIDRARE, J., 2001. n-3 polyunsaturated fatty acids and cardiovascular health. Lipids. 36 (Suppl.): 127S-128S.

NORRISH, A.E., SKEAFF, C.M., ARRIBAS, G.L.B., SHARPE, T.W., NICHOLS, P.D., 2001b. Utilisation of fish oil in ruminants. Case- control study. Br. J. Cancer. 81: 1238-1242.

OKEUDU, N.J., MOSS, B.W., CHESTNUTT, M.B., 1994. Effect of feeding a milk diet or concentrate plus hay diet on carcass and meat quality of lamb. Page 38, S. IV A, in Proc. 40 th Int. Congr. on Meat Science and Technology, The Hague, The Netherlands.
Suckling lamb performances

Perez, P., Maino, M., Tomic, G., Mardones, E., Pernia, J., 2002. Carcass characteristics and meat quality of Suffolk Down suckling lambs. Small Ruminant Res. 44: 233-240.

Peters, R., Rux, G., van Isterdael, J., 1996. Environmental and maternal effects on early postnatal growth of lambs of different genotypes. Small Ruminant Res. 19: 45-53.

Pinna, W., Piccolo, V., Lai, P., Cappio Borlino, A., 1994. Produzione dell’agnello da latte: allattamento materno vs allattamento artificiale con un sostitutivo acido. Nota III. Rilievi alla macellazione e composizione della carcassa. pp 161-164 in Proc. 11th Nat. Congr. SIPAOC, Perugia, Italy.

Piva, G., Mazzocchi, M., Meschini, M., Calabrese, G., Grandini, A., 1998. Effetto dell’aggiunta di diverse fonti lipidiche a diete per galline ovaiole sulle performance e sulle caratteristiche qualitative del l’uovo. Riv. Avicoltura. 67(5): 52-57.

Ponnampalam, E.N., Sinclair, A.J., Egan, A.R., Blakeley, S.J., Leury, B.J., 2001a. Effect of diets containing n-3 fatty acids on muscle long-chain n-3 fatty acid content in lambs fed low - and medium quality roughage diets. J. Anim. Sci. 79: 696-706.

Ponnampalam, E.N., Sinclair, A.J., Egan, A.R., Blakeley, S.J., Li, D., Leury, B.J., 2001b. Effect of dietary modification of muscle long-chain n-3 fatty acid on plasma insulin and lipid metabolites, carcass traits, and fat deposition in lambs. J. Anim. Sci. 79: 895-903.

Ponnampalam, E.N., Trout, G.R., Sinclair, A.J., Egan, A.R., Leury, B.J., 2001c. Comparison of the color stability and lipid oxidative stability of fresh and vacuum packaged lamb muscle containing elevated omega-3 and omega-6 fatty acid level from dietary manipulation. Meat Sci. 58: 151-161.

Ragni, M., Vicenti, A., Melodia, L., Caputi Jambrenghi, A., Facchiongolo, A.M., Vonghia, G., 2001. Impiego di acidi grassi omega-3 nell’allattamento artificiale per la produzione del capretto. 1. Effetti sulle prestazioni zootecniche e sulle caratteristiche delle carcasse e delle carnii. Zoot. Nutr. Anim. 27: 15-22.

Rattray, P.V., Garret, W.N., Meyer, H.H., Bradford, G.E., East, N.E., Hinsman, N., 1973. Body and carcass composition of Targhee and Finn-Targhee lambs. J. Anim. Sci. 38: 613-626.

Ruíz de Huidobro, F., Canque, V., 1994. Produccion de carne en corderos de raza Manchega. III. Composición tisular de las canales y de las piezas. Meat production of Manchega lambs. III. Carcass and cuts tissue composition. Invest. Agric. Sanid. Anim. 9: 57-69.

Sahlu, T., Carneiro, H., El Shaker, H.M., Fernandez, J.M., 1992. Production performances and physiological responses of Angora goat kids fed acidified milk replacer. J. Dairy Sci. 69: 1871-1883.

Sanudo, C., Campo, M.M., Sierra, I., Maria G.A., Olleta, J.L., Santolari, F., 1997. Breed effect on carcass and meat quality of suckling lambs. Meat Sci. 46: 357-365.

Sanudo, C., Sierra I., Olleta, J.L., Martin, L., Campo, M.M., Santolari, F., Wood, J. D., Nute, G.R., 1998. Influence of weaning on carcass quality, fatty acid composition and meat quality in intensive lamb production systems. Anim. Sci. 66: 175-187.

SAS (1999-2000) SAS/STAT® Guide for Personal computers, Version 8.1 Edn. SAS Institute Inc., Cary, NC, USA.

Sevi, A., Muscio, A., Casamassima, D., 1996. Recent acquisizioni sull’allattamento artificiale dell’agnello. Agr. Ric. 18: 431-440.

Sheard, N.F., 1998. Fish consumption and risk of sudden cardiac death. Nutr. Rev. 56(6): 177-179.

Sim, J.S., 1997. Designer eggs and their nutritional and functional significance. World Rev. Nutr. Diet. 83: 89-101.

Simopoulos, A.P., 1997. Overview of evolutionary aspects of omega-3 fatty acids in the diet. World Rev. Nutr. Diet. 83: 1-11.

Stubs, C.D., and Smith, A.D., 1984. The modification of mammalian membrane polyunsaturated fatty acid composition in relation to membrane fluidity and function. Biochim. Biophys. Acta. 779: 89-137.

Uauy, R., Treen, M., Hoffman, D., 1989. Essential fatty acid metabolism and requirements during development. Semin. Perinatol. 13: 118-130.

Van Oeckel, M.J., Castells, M., Warrantas, N., Van Damme, L., Bouquey, C.V., 1996. Omega-3 Fatty Acids in Pig Nutrition: Implications for the Intrinsic and sensory quality of the meat. Meat Sci. 44: 55-63.

Velasco, S., Canque, V., Perez, C., Lauzurica, S., Diaz, M.T., Huidobro, F., Manzanarias, C., Gonzalez, J., 2001. Fatty acid composition of adipose depots of suckling lambs raised under different production systems. Meat Sci. 59: 325-333.

Vergara, H., Gallego, L., 1999. Effect of type of suckling and length of lactation period on carcass and meat quality in intensive lamb production system. Meat Sci. 53: 211-215.

Verita, P., Ciang, D., 1992. Le tecniche di allevamento ovino-pecorino e l’alimentazione. In: UNAPOC (ed.) Ovinicoltura. UNAPOC, Roma, Italy, pp 73-101.

Vicenti, A., Ragni, M., Giannico, F., Vonghia, G., Zizza, L., 2001. Impiego di acidi grassi omega-3 nell’allattamento artificiale per la produzione del capretto. 1. Effetti sulla composizione chimica e sul profilo acido delle carnii. Zoot. Nutr. Anim. 27: 23-32.

Whan Zahari, M., Thompson, J.K., Sott, D., Topps, J.H., Buchan, W., Pennie K., 1989. Effect of growth rate on mineral retention and body composition of growing lambs. Anim. Prod. 49: 443-450.

William, J.A., John, A.G., Srivivas, T.R., David, R., David, H., Delprat, B., 2001. Modulation of omega-3/omega-6 polyunsaturated ratios with dietary fish oils in men with prostate cancer. Urology. 58: 283-288.