The effects of artificial rearing and fostering on the growth, carcass and meat quality of lambs

Samantha J. Ward [a1], Marimar Campo[b] and Guiomar Liste[a2]

[a] *Animal Welfare & Management, Moulton College, West Street, Moulton, Northampton NN3 7RR, UK*.

[b] *Department of Animal Production and Food Science, University of Zaragoza, Miguel Servet 177, 50013, Zaragoza, Spain.*

[1] Present address: *Animal, Rural & Environmental Sciences, Nottingham Trent University, Brackenhurst Campus, NG1 4BU, UK.*

[2] Present address: *Animal Behaviour, Welfare and Ethics Group, Royal Veterinary College, Hawkshead Campus, Hatfield, AL9 7TA*, UK.

Corresponding author: Dr. Guiomar Liste. glisteruiz@rvc.ac.uk

Abstract

Lamb rearing is a key point to ensure good quality at the end of the production cycle. Fostering and artificial rearing are techniques commonly used when natural rearing is compromised. However, there is a lack of research investigating their impact on the product´s quality, especially when lambs are slaughtered late, around 6 months of age. The current study investigated the effects of artificially reared and fostered lambs on growth, carcass and meat quality. The three foster methods under study were birth fluids, cervical stimulation combined with birth fluids and restraint. Animals were weaned at 3 months of age, and processed at 6 months of age. Artificially reared lambs presented lower weight gains than ewe reared ones at young ages. They also presented worse conformation scores at the processing plant. No differences could be found for growth rates, carcass or meat quality among the foster methods tested.

Keywords

Lamb; Fostering; Artificial rearing; Carcass quality; Meat quality.

1. Introduction

In 2013, the world´s production of sheep meat surpassed 8.589 million tonnes, with Europe producing around 1.130 million tonnes (FAOSTATS, 2016). In the specific case of the English lamb industry, it has been estimated that only 54% of lambs reach acceptable market requirements (EBLEX 2007). Subsequently, if the UK produces around 289,000 tonnes of sheep meat per year (FAOSTATS, 2016) this could theoretically indicate that a large amount of meat could be potentially wasted because of lambs not reaching acceptable market requirements. An important aspect to ensure that lambs reach an acceptable market standard is the proper care from birth and appropriate use of husbandry techniques (Diaz et al., 2002; Chestnutt, 1994). A key step during lamb rearing is weaning, and its effects (early vs. late) on carcass and meat quality have been widely studied (Cañeque et al*.,* 2000; Napolitano et al., 2002; Norouzian and Valizadeh, 2011; Ekiz et al., 2012). In general, late weaning is associated with better growth rates and conformation scores but regarding meat quality no significant effects have been usually reported. These effects on growth and carcass quality are traditionally linked to the physiological changes needed to switch from a liquid to a solid food source and its repercussions in overall intake (Cañeque et al*.,* 2000). There is also extensive literature on the effects that artificial vs. maternal rearing has on lambs at weaning (Napolitano et al., 2006; Norouzian and Valizadeh, 2011). Most studies conclude suggesting that initial weight differences at weaning can be found, but with no lasting effects on carcass characteristics at time of slaughter. Some other studies though (Lanza et al., 2006; Vicenti et al., 2004) have reported significant differences on carcass weight, meat colour and fat contents with lambs fed on ewe milk being heavier, with lighter meat colour and lower fat content. Conversely, Napolitano et al., (2002) reported that the artificially-reared lambs produced better quality meat than lambs receiving ewe milk (significantly higher carcass yield percentage, second grade cut percentage and significantly less leg fat percentage). Fostering is a rearing technique commonly used within the lamb industry worldwide. However, there is a lack of research investigating its impact on the quality of the resulting products, especially in production systems where lambs are slaughtered late, around 140-180 days old, such as the UK industry.

The current study investigated the differences between artificially reared (AR) and fostered lambs on growth and live morphometric indices, carcass quality and meat quality. The three foster methods under study were birth fluids (BF), cervical stimulation combined with birth fluids (CSBF) and restraint (R). The present paper was part of a larger study investigating the effects of different foster methods on the welfare of ewes, where R ewes presented higher cortisol levels and lowered maternal behaviours representing compromised welfare (Ward et al. in preparation). These rearing treatments were compared to control ewes raising their own twins in a commercial setting where lambs were weaned at 3 months but kept grazing until slaughter at 6 months of age. If differences were still present among treatments at the time of slaughter this could mean long-term implications of distress early in life, implications that could not be resolved by a long compensatory post-weaning period. If foster methods such as R, detrimental to ewe welfare as mentioned above, were to affect lamb performance as well, they should be considered not suitable and their use discouraged.

2. Materials and Methods

2.1. Animals

Moulton College Sheep Farm (Northampton, UK) is home to approximately 1000 North Country mule ewes. 84 ewes in total were monitored during two lambing seasons (spring 2009 and 2010) for the current experiment. Experimental ewes were multiparous (n = 48) or primiparous (n = 36). A total of 180 North Country mule lambs, of both genders (97 females and 83 males), classified as natal (raised by their own mother), alien (fostered) or AR (bottle fed) were included in the current experiment.

2.2. Housing and husbandry

Ewes were naturally mated and grazed outdoors until approximately four weeks prior to lambing. They were then housed together in large covered sheds according to their pregnancy scan results, creating three groups: singles, twins or triplets. At lambing, ewes were left on their own unless difficulties arose, in which case an experienced shepherd aided delivery. Each ewe and its lamb/s were relocated to an individual pen (1.52m x 1.14m) within four hours from delivery time, where interference from other ewes was avoided and maternal bonds could be better established. After four hours in the individual pen, the lambs were routinely checked and treated (ear tagging and treatment of the navels and watery mouth). The fostered and AR lambs were selected from ewes giving birth to triplets. A triplet was allocated a foster dam from the group giving birth to single lambs and housed in an individual pen; the fostering method was then applied choosing among the three treatments to be tested (see Table 1). For the R treatment, special restraint pens measuring 1.20mx1.10m were used.

2.3. Treatments

Foster was performed immediately after the single-bearing ewe delivered her lamb, if any recent triplets were available. Weights at birth and lamb gender were allocated to try and create the most homogeneous treatment groups possible, but as the work was carried out in commercial facilities these confounding effects could not be completely balanced. The treatment groups were classified as birth fluids foster (BF, N=48 lambs); cervical stimulation combined with birth fluids foster (CSBF, N=24 lambs), restrained foster (R, N=48 lambs), AR lambs (N=12 lambs) and the control group (N=48 lambs). Only successful fosters were included in the study, as the purpose was to investigate the long term implications of different fostering techniques. BF treatment (from 12 primiparous and 12 multiparous ewes, 48 lambs in total) consisted in coating the alien lamb with the birth fluids from the single lamb-bearing fostering ewe. CSBF treatment (from 12 multiparous ewes only, 24 lambs in total) involved the shepherd gently pushing his hand into the cervix of the single-lamb bearing fostering ewe and simulating contractions by opening and closing the hand at ten seconds intervals. Then the shepherd coated the alien lamb using the foster ewe' birth fluids. Due to the fragile nature of primiparous ewes CSBF was not performed on them. R treatment (from 12 primiparous and 12 multiparous ewes, 48 lambs in total), was conducted in specific pens where the ewes heads were locked outside by the neck between vertical bars. The lambs were then placed inside the pen, behind the ewe's head. The restraint pens enable the ewes to lie down, stand and have access to food and water. However they inhibit its ability to look and sniff at the lambs. The ewes were left in the restraint pens for a maximum of 5 days, depending on their level of acceptance of the lamb and the lambs' ability to successfully feed. These three fostering methods were selected for the experiment because it was previously found that they were the most commonly used by UK farmers (Ward et al., 2011). A random sample of 24 ewes (12 primiparous and 12 multiparous, 48 lambs in total) were selected from the group of ewes scanned as twins and used as controls. AR lambs (*n*=12) were placed in a lambing pen provided with a heat lamp and were initially force fed natural cow colostrum sourced from the Moulton College dairy unit using a stomach tube. Subsequent feedings took place every three hours with warm artificial milk powder (*Lamb Force ewe milk* replacer, Downland®; Carlisle, UK) mixed at 20g of milk powder for 250ml of warm water. Each lamb was fed from individual bottles at a rate of 50ml per kg of body weight. This milk powder contained 23% oils, 23% protein and 8% ash, and it was enriched with vitamins A, D_3, E and Selenium. Bottle feeding occurred individually, with three persons (two stockpersons and one researcher) taking turns to bottle feed the 12 AR lambs every three hours for their first 2 weeks of life (during the lambing season). The authors acknowledge that this technique is potentially less adequate to feed AR lambs than *ad libitum* feeding through automatic equipment, but it is still a common occurrence in small to medium UK farms and thus valid to be studied. These lambs were weaned (all milk supplements removed) at 3 months of age as the other experimental lambs.

After three days, experimental ewes and lambs were identified with spray markers and relocated into group mothering pens of approximately $400m^2$. These pens were also covered areas within the lambing sheds which housed up to 10 ewes and their lambs. When lambs were at least one week old, ewes and lambs were taken to the surrounding fields remaining in outdoor grass pastures with supplementary feeding of lamb creep pellets. At around three months of age, all experimental lambs were weaned, and kept grazing in the same fields without their dams until approximately six months of age when they were sent to slaughter. The trial was approved by the ethical committee at Moulton College and the University of Northampton and followed the ARRIVE guidelines where necessary. As the animals were not subjected to stressful manipulations other than those included in routine farm rearing, no other licenses or permits were needed for the study.

2.4. Data collection

Pre-Slaughter data

All lambs were weighed and measured on their date of birth (day 0) and then on days 7, 30, 90 and 180. These days were chosen as coincident with relevant husbandry procedures. Day 7 referred to the weight/measures before the lambs were put out to pasture. Day 30 coincided with the routine medication for the lambs (fly-strike and prophylactic endoparasitic treatment). Day 90 represented weight/measures at weaning. Finally, day 180 corresponded to weight/measures of the finished lambs, on the day prior to slaughter. Weights were taken using a digital spring balance (Portable Electronic Scale, OCS-1, London, UK) with the lambs placed in a bucket until they reached 20kg (30 days of age). Salter Brecknell® LS300 (Brecknell®, West Midlands, UK) weighting scales were used for 90 and 180 day weights. Daily weight gain was calculated for the first week of life (period 1), between day 8 and 30 (period 2), between day 31 and 90 (period 3) and from day 91 to 180 days, when lambs were slaughtered (period 4). Average daily gain for the whole experiment was also calculated. Additional morphometric measurements were taken including external body length (BL; base of neck to beginning of tail), torso length (TL; shoulder to ischium), height at shoulder (HS; floor to shoulder), rump length (RL; Ilium to ischium), rump width (RW; left ilium to right ilium), chest depth (CD; largest depth of ribs at shoulder) and chest circumference (C). BL, TL, HS, RL and C were taken using a measuring tape and a calliper was used for RW and CD. Several indices were calculated from the measures taken: relative torso depth (RTD = (CD/HS) x 100), pelvic index (PEI = (RW/RL) x 100), transversal pelvic index (TPI = (RW/HS) x 100), longitudinal pelvic index (LPI = (RL/HS) x 100), body index (BI = (TL/C) x 100), relative shortness index (RSI = (TL/HS) x 100), compactness index (CI = (weight/BL) x 100), relative weight index (RWI = (weight/HS) x 100) and proportionality index (PRI =(TL/HS) x 100). All indices were calculated for each weighing/measuring day (day 0, 7, 30, 90 and 180).

Post-Slaughter data

Joseph Morris abattoir and butchery (EU approved; South Kilworth, Leicestershire, UK) was selected to minimise travelling distance. The average journey length was 35 minutes for all experimental lambs. On the day of slaughter, animals were loaded at 05.00 am into an Ifor Williams® DP120 (model: 10’x6’ H/R) livestock trailer. On arrival to the abattoir, the animals were unloaded into the lairage area which consisted of concrete flooring with solid metal separation gates between pens of approximately 8.6 m^2. Animals were housed in their travelling groups and remained in this area for 30 minutes. The lambs were slaughtered using electrical stunning then bled out immediately. Carcasses were kept in the abattoir´s cold storage room at 4ºC for 24h after processing.

On the day of slaughter, conformation and fatness scores were recorded using the EUROP system on the experimental carcasses at the end of the processing line. Conformation was graded as E, U, R, O or P, where E was classified as excellent and P classified as poor. Fatness was graded as 1, 2, 3, 4 or 5 where a grade 1 was very lean and grade 5 was very fat. An additional set of carcass measurements were taken to assess carcass quality, including chest width (Wr; widest carcass measurement at the ribs), chest depth (Th; maximum distance between the sternum and back of the carcass at the sixth thoracic vertebra), buttock length (G; widest buttock measurement in a horizontal plane), leg length (F; length from perineum to distal edge of the tarsus) and internal carcass length (L; length from cranial edge of the pelvic symphysis to the cranial edge of the first rib). Th, Wr and G were measured using a calliper and a measuring tape was used for L and F. Two carcass conformation indices were also calculated: chest roundness index (Wr/Th x 100) and buttock/leg index (G/F). Ultimate pH was assessed 24h *post-mortem* at the *Longissimus dorsi lumborum* level using a 507 spear tip electrode with portable pH meter (Crison®, Barcelona, Spain). Cold carcass weights (CCW) were also recorded at this point and carcass compactness (CCW/L x 100) and commercial dressing indices (CCW/slaughter weight x 100) were calculated.

The lambs were then butchered and the left loin *(Longisimus dorsi thoracis et lumborum)* was removed and taken to the laboratory at Moulton College without breaking the cold chain (by placing samples inside Styrofoam boxes and covering them with ice packs). Once at the laboratory, a slice of the loin, approximately 3cm wide, was separated for the colour measures while a second piece, of a minimum of 30g, was also separated for the water holding capacity (WHC) assessment. Both pieces were placed into polystyrene boxes, covered with O_2 permeable film and stored in the fridge at 4ºC for a further 24 hours. Colour readings were measured at 36 hours *post-mortem* (including 24h of blooming) with a MINOLTA® colorimeter (model: CR-200b) to measure lightness (L*), redness (a*) and yellowness (b*) of the meat samples in the CIEL*a*b* space, with an Illuminant

D65 and a 10º observer. Each sample was measured three times and an average score was calculated for each parameter. WHC was also measured 36 hours *post-mortem* and was expressed as the percentage (%) of expelled juice after compression, using the Grau and Hamm Method as outlined by Beriain et al., (2000).

2.5. Statistical analysis

SPSS® version 17 was used for the statistical analysis of all data, which proved to be normally distributed. Mean daily weight gains for the ewe-reared lambs were analysed using general linear models with lamb origin (natal/alien), foster method (BF or R) and ewe experience (primiparous or multiparous) as independent variables. Rearing type (ewe-reared, fostered or artificially-reared, compared to controls) was analysed using Kruskal Wallis tests due to the unequal group sizes between the AR, controls and pooled ewe-reared data (for the three foster treatments). Investigations were performed separately for each time period. Conformation and fatness scores were converted into numerical data for statistical analysis (assigning numbers from 1, for P-, up to 15, for E+, regarding conformation scores, and again numbers from 1, for 1-, up to 15, for 5+, regarding fatness scores). Carcass and meat quality parameters including CCW, conformation, fatness, commercial dressing, chest roundness index, buttock/leg index, carcass compactness index, ultimate pH, WHC and colour (L*, a*, b*), were also analysed using a general linear model with the foster method, ewes' experience and lamb origin as independent variables. Rearing type was again analysed using a Kruskal Wallis test with the inclusion of data for artificially reared lambs, fostered lambs and controls.

3. Results

3.1. Pre-Slaughter data

Given the lack of statistically relevant differences among foster methods for any of the variables analyzed, results are presented grouped as one general foster treatment. There was a significant rearing effect on daily weight gain on period 1, period 2 and period 3 with lambs reared by ewes gaining significantly more weight than AR lambs ($P<0.001$ for periods 1 and 2, and $P<0.05$ for period 3). However, period 4 did not show any significant differences between ewe and AR lambs

(Figure 1). Figure 2 shows the results for the live morphometric measurements and indices when comparing ewe-reared (foster and control) vs. AR lambs. No significant differences were found in any of the indices at 180 days as expected, most likely due to the compensatory growth occurring after weaning within the commercial long-rearing system. However, significant differences were found in all indices at some stage within the rearing period with ewe-reared lambs showing significantly better indices. When considering the effect of fostering, there were no differences in daily weight gain or live morphometric measurements among the different foster methods. Weights at day 0 and day 7 showed that natal lambs were significantly heavier than alien lambs ($P<0.05$) as expected, however at days 30, 90 and 180 the differences had disappeared. There were no significant differences found between the average daily weight gain of the natal compared to the alien lambs for any of the time periods analysed. Results suggest that ewe experience affected weight gain, with lambs reared by multiparous ewes, gaining significantly more weight during periods 1, 3 and 4 ($P<0.001$ in all cases, see Table 2).

3.2. Post-slaughter data

When comparing the carcass quality of lambs subjected to different rearing conditions, results suggest that ewe-reared lambs had significantly better conformation scores and chest roundness indices than AR lambs ($P<0.01$ and $P<0.05$ respectively; Table 3). Other parameters were not found to be affected by rearing condition including slaughter weight. There were no significant differences for any of the carcass or meat quality parameters among foster methods. This was also the case for the comparison between alien and natal lambs. The ewes' experience had a significant impact on the live slaughter weight and cold carcass weight ($P<0.05$ in both cases, see Table 2) with the multiparous ewes rearing significantly heavier lambs compared to the primiparous ewes. The ultimate pH was also significantly affected by the ewes' experience with the multiparous ewe lambs showing significantly lower pH values ($P<0.05$, see Table 2). The remaining carcass and meat quality parameters showed no significant differences between multiparous and primiparous ewes.

4. Discussion

Results showed that for at least the initial three months of life, before weaning, the artificial rearing of lambs under the conditions of the current study significantly reduced the lambs' daily weight gain. The use of any fostering method was beneficial when compared to AR, and fostered animals followed a similar growth rate to the control lambs. These results coincide with work by Oztabak and Ozpinar (2006) and Napolitano et al., (2006) that showed that average daily weight gain for ewe-reared lambs was significantly higher than for AR lambs, from birth up until 21 days. However, Napolitano et al., (2002) and Sevi et al., (2003) found no differences between the AR and ewe-reared lambs average growth rates. The contradictory results are most likely due to the *ad libitum* basis feeding of the previous studies, therefore having access to milk at all times. Due to the setting of the current study, this feeding apparatus was not available and the AR lambs had feeding sessions every three hours which was similar to the setup from Oztabak and Ozpinar (2006). In general, morphometric indices were found to evolve normally with age. Those indices directly linking height/length measures with weight (compactness and relative weight index) showed a steady increase up until weaning and a drop afterwards, as it was expected according to age variations on bone growth rate and muscle and body fat deposition (Riva et al. 2004). Morphometric indices at varying points between 0 and 90 days of age were found to be significantly better for the ewe-reared lambs compared to the AR lambs, which suggests that AR lambs were not growing at the same rate as ewe-reared lambs, up until weaning. Previous studies have found that there are strong correlations between body weight and live morphometric measurements (Alderson, 1999; Arthur and Ahunu, 1989; Ribeiro et al., 2004) with different body features being more prominent at different ages in growing lambs, and results from the current study agree. The daily weight gain and the morphometric indices showed no differences between the rearing treatments between 91 and 180 days (period 4). This period of time corresponded to the after-weaning rearing and all animals were fed on grass with access to the same pastures; it seems that, as expected, AR lambs were able to compensate their weight gain during this period of equal resource availability. Norouzian and Valizadeh (2011) also found that after weaning the growth rates were not affected by the rearing treatment. Additionally to the results from the current experiment, artificial rearing has been associated with a reduction in animal welfare probably due to the impact of the physiological and psychological stressors caused by the early separation of the lamb and ewe (Cockram et al., 1993; Napolitano et al., 1995; Napolitano et al., 2002)

Regarding the potential separate effects of each fostering technique, neither the average daily gain nor the morphometric indices varied among the three foster methods studied, for any of the time periods analysed. These daily gains and indices did not differ from those of control twins either. This was due to the fact that experimental lambs came from successful fosters only. However, alien lambs were significantly lighter than the natal lambs at 0 and 7 days of age, which is due to the fact that alien lambs were born as triplets and natal lambs as singletons. These weight differences have been already observed in previous studies (Hernandez et al., 2009, Snowder and Knight, 1995). Although the lamb weights were different for the initial week of life, there were no significant differences in the daily weight gain between alien and natal lambs, which suggest that both were able to feed as needed. Weights and average daily gain for the alien and natal lambs at 30, 90 and 180 days of age did not show significant differences between them. This seems to indicate that successful fosters, even if including a lighter and potentially weaker lamb, can produce similar results to lambs being reared by their own dam. It was found that multiparous ewes raised heavier lambs, with significantly higher weight gains, than primiparous ewes during periods 1, 3 and 4. No previous research has compared the rearing ability of North Country mules with respect to growth rates. However, these results could be linked to the better ability of multiparous ewes to stimulate the lambs to suckle and encourage them to feed (Dwyer and Lawrence, 2000) and also due to the fact that primiparous ewes generally produce lighter offspring, which has been linked to their lower bodyweight and age at lambing (Dwyer, 2003). These results suggest that when selecting ewes for fostering, an experienced ewe would be more beneficial to ensure a high daily weight gain for each lamb compared to a primiparous ewe. Behavioural and cortisol results from these same experimental ewes (presented and discussed in Ward *et al.* in preparation) showed that primiparous ewes spent less time tending to their lambs and had significantly higher cortisol levels compared to multiparous ewes. This suggests that, not only do primiparous ewes produce lighter offspring, but also perform different behaviours than experienced dams and are more influenced at the physiological level by parturition and fostering.

Rearing was found to have a significant effect on conformation scores and chest roundness index with ewe-reared lambs achieving higher scores than AR lambs. Further research in this area would be advantageous to investigate effects of rearing on carcass quality, as some farmers are paid according to carcass conformation in addition to weight. Although carcass conformation is a common quality parameter used at the abattoir level, it is a subjective measure and caution is needed if using it alone. The majority of carcass quality parameters assessed on the current study were not found to be different between the rearing treatments due to the late slaughter age (6 months of age) and the long post-weaning period (90 days) spent grazing under similar conditions, which provided enough time for any potential differences from the nursing period to even out. These results were also expected, but it is difficult to draw comparisons from them to the available bibliography because most literature has been conducted with lambs slaughtered at an earlier age. Regarding the potential separate effects of each fostering technique, carcass and meat quality parameters did not differ among foster methods. No differences were either found for the comparison between lambs' origin (alien vs. natal). It has been suggested that fostering and AR cause ewe-lamb bonds to be broken which can be distressing, and that distress during the initial stages of life could have detrimental effects on the lambs' behaviour, immune and endocrine status (Napolitano, 2003). Early life distress and its consequences could also ultimately influence carcass quality (Gregory, 1998). However, the current results imply that any potential distress caused by fostering or AR did not have long-term implications on the carcass or instrumental meat quality at a slaughter age of 180 days.

Multiparous ewes were able to rear lambs with significantly higher live slaughter weight and cold carcass weights than primiparous ewes. This could be linked again to the increased experience of multiparous ewes and their ability to produce more milk and to better attend lambs. The ultimate pH was also significantly lower in lambs reared by multiparous compared to primiparous ewes. The pH of the lambs reared by primiparous ewes fell slightly out of the normal range for this type of meat (5.4 - 5.8). A high ultimate pH can cause undesirable odours and flavours, affect palatability and reduce storage time compared to meat with a lower pH (Pethick and Jacob, 2000). High pH levels have been linked to many forms of acute distress including heat, transportation, dehydration, hunger, injury and fear (Ferguson and Warner, 2008). But it is difficult to find an explanation to this result because only data indicative of distress in the current study was taken at time of birth (behaviour, cortisol and heart rate frequencies, Ward et al. in preparation). Early life distress could be having an effect on the lambs' temperament, and it has been shown that nervous temperament associates with stronger fear reactions (Bickell et al., 2011) which could have had an effect under slaughter conditions on meat quality indicators. However, more research is needed in this area to clarify these results and hypotheses.

The current study investigated growth rates, carcass and meat quality parameters for lambs within a commercial farming system using a 6 months slaughter age. Differences were noted between AR and ewe-reared lambs' average daily gain at young ages, as seen in previous studies. However, due to the extended post-weaning period where all lambs were grazing together, any differences were compensated and AR lambs produced similar meat quality results as ewe-reared lambs. AR lambs however did show significantly lower conformation scores and chest roundness indices, suggesting that ewe-rearing, and therefore fostering, could offer some advantages even when working at late slaughter ages. A lack of differences between growth rates, carcass and meat quality characteristics among the different foster methods, and also between alien and natal lambs, showed that once a foster of any type was successfully established, the alien lamb was enabled to feed similarly to the natal lamb and gain weight at the same rate as the natal lamb. Multiparous ewes were capable of rearing heavier lambs with higher average daily gains than primiparous ewes therefore suggesting that they would be better suited for fostering. Choosing foster methods should then be based on success rates and implications for the ewes' welfare (Ward et al. in preparation), as implications for the lambs' performance seem to be negligible. In conclusion, ewe-rearing and successful fostering seem to offer some proven advantages over AR under the conditions of the current study, even at late slaughter ages, and multiparous ewes seem to be better candidates as fosterers than primiparous ewes.

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Table 1: Summary of experimental treatments and animals involved, expressed as: number of lambs (number of ewes). BF = birth fluids, CSBF = cervical stimulation and birth fluids, R = restraint.

	CONTROL, *ewe reared*	**FOSTERED, *ewe reared***			**ARTIFICIALLY REARED**
		BF	**CSBF**	**R**	
Primiparous	24 (12)	24 (12)	-	24 (12)	-
Multiparous	24 (12)	24 (12)	24 (12)	24 (12)	-
TOTAL	48 (24)	48 (24)	24 (12)	48 (24)	12

Table 2: Mean (± SE) for the different growth rates and carcass quality parameters for lambs slaughtered at 180 days according to ewe's experience. Different superscripts in the same row indicate significant differences at $p < 0.05$, a-b and $p < 0.001$, c-d.

		Ewe experience	
		Primiparous	**Multiparous**
Average Weight Daily Gain	Period 1	0.23 ± 0.06^{a}	0.27 ± 0.11^{b}
	Period 2	0.30 ± 0.08^{a}	0.31 ± 0.08^{b}
	Period 3	0.27 ± 0.04	0.31 ± 0.08
	Period 4	0.22 ± 0.03^{a}	0.27 ± 0.06^{b}
Carcass Quality	Live Slaughter Weight	44.79 ± 2.06^{c}	50.19 ± 1.92^{d}
	Cold Carcass Weight	23.89 ± 1.47^{c}	25.77 ± 1.42^{d}
	Ultimate pH	5.78 ± 0.02^{c}	5.82 ± 0.02^{d}

Table 3: Mean (± SE) for the different carcass and meat quality parameters for lambs slaughtered at 180 days according to their rearing methods. Different superscripts in the same row indicate significant differences at $p < 0.05$. Chest Roundness Index = (chest width/chest depth) x 100; Buttock/Leg Index = buttock length/leg length; Carcass Compactness = (cold carcass weight/internal carcass length) x 100; Chest Depth Index = (cold carcass weight/slaughter weight) x 100.

	Ewe Reared		
Parameters	**Control**	**Fostered**	**Artificially Reared**
Live Slaughter Weight	46.66 ± 2.10	48.45 ± 1.97	43.46 ± 1.20
Cold Carcass Weight	23.04 ± 1.39	23.65 ± 1.37	20.51 ± 0.85
Conformation score	10.05 ± 0.39[a]	10.66 ± 0.45[a]	8.90 ± 0.56[b]
Fatness score	7.68 ± 0.19	8.22 ± 0.28	8.00 ± 0.30
Ultimate pH	5.80 ± 0.02	5.80 ± 0.02	5.81 ± 0.02
Water Holding Capacity	19.36 ± 0.47	19.35 ± 0.32	19.37 ± 0.31
L* (Lightness)	35.52 ± 0.79	34.50 ± 0.86	35.67 ± 0.32
a* (Redness)	7.04 ± 0.04	7.01 ± 0.93	6.99 ± 0.08
b* (Yellowness)	3.31 ± 0.05	3.32 ± 0.08	3.25 ± 0.13
Chest Depth Index	48.97 ± 5.20	47.27 ± 4.37	47.38 ± 2.19
Chest Roundness Index	91.55 ± 2.56 [a]	89.72 ± 2.57 [a]	81.85 ± 3.44 [b]
Buttock/Leg Index	69.54 ± 2.01	73.04 ± 2.46	76.01 ± 1.06
Carcass Compactness	35.12 ± 3.08	35.76 ± 2.99	35.29 ± 1.25

Figure captions

Figure 1. Daily weight gains across the different foster method treatments and artificially reared lambs. Different letters indicate significant differences (a-b, $p < 0.05$; c-d, $p < 0.005$). Period 1 = average daily gain from day 0 - 7, Period 2 = average daily gain from 8 - 30, Period 3 = average daily gain from 31 – 90, Period 4 = average daily gain from 91 – 180 and TOTAL = average daily gain from day 0 to 180 for all treatments. Data markers represent means ± SE.

Figure 2: Indices calculated from live morphometric measurements (means ± SE) assessed at 0, 7, 30, 90 and 180 days of age. Different letters indicate significant differences (a-b, $p < 0.05$; c-d, $p < 0.005$). **2a.** Pelvic Index = (rump width/rump length) x 100; Transversal Pelvic Index = (rump width / height at shoulder) x 100; Longitudinal Pelvic Index = (rump length/height at shoulder) x 100 **2b.** Relative Torso Depth = (chest depth/height at shoulder) x 100; Compactness Index = (weight/ body length) x 100; Relative Weight Index = (weight/ height at shoulder) x 100 **2c.** Body Index = (torso length/chest circumference) x 100; Proportionality Index =(torso length/ height at shoulder) x 100; Relative Shortness Index = (torso length/ height at shoulder) x 100.