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Adding value to cull cow beef

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1. Summary

- A high proportion of cull dairy (78%) and beef (50%) cows slaughtered off Irish farms at the end of the grazing season are under-finished.
- A live weight > 620 kg and a body condition score >3.5 should be targeted to achieve the target carcass; cold carcass weight > 272 kg, carcass conformation class P+ and a carcass fat class 3.
- Increasing concentrate proportion in the diet of cull dairy cows decreased days to slaughter. Increasing concentrate proportion > 6 kg DM/cow/day had no advantage in ADG.
- Younger cows (≤2 lactations) are more responsive to finish feeding strategies than older cows (≥7 lactations) in terms of live animal response (ADG and days to slaughter).
- Cold carcass weight increased by 0.22 when finishing diets were offered.
- A target ADG of 1.0 kg/cow/day at pasture is achievable when finishing cull dairy cows.
- LW and BCS were useful predictors of cold carcass weight (R^2 0.81) but were of limited value for prediction of carcass conformation class and carcass fat class.
- The most economically viable finishing strategy evaluated under varying farm resources and management alternatives was the EXTLAC (extended lactation) strategy achieving €283 net profit per cow.
- Variations in management strategies compared with dietary strategies had greater return in profit margin, predominantly due to the increase in proportion of grazed grass in the finishing diet.

2. Introduction

This project addressed the prospects of increasing the value of cull cow beef and examined the potential of a number of different management and dietary strategies. In Ireland, the national cow herd contributes 350,000 animals to total beef production annually, which represents 22% of all cattle slaughtered (DAF, 2007). A dominant feature of beef production in Ireland is the disposal of cows from the dairy and beef industries, the time of year at which culling occurs influences the number of cows available for slaughter. Suitability of a cow for slaughter is generally not a consideration for dairy or beef farmers.

Cull cow sales are a potential source of income on Irish dairy farms, and may be of particular relevance in an era of downward pressures on milk prices and milk quota restrictions. With rising costs of production at farm level, finishing cull dairy cows may be an option for dairy farmers. Several studies have demonstrated that increasing the plane of nutrition for cull cow's pre-slaughter will improve carcass and meat quality characteristics (Vestergaard et al., 2007).

Maximising the proportion of grazed herbage in the diet of livestock regardless of enterprise (dairy or beef) has a central role in increasing the competitiveness of Irish production systems. Traditionally, beef finishing systems in Ireland offer a diet of grass silage, concentrate and/or grazed grass (Keane and Drennan, 2000). The cost of grass silage production continues to escalate, while beef support payments decline. Renewed interest in investigating methods of reducing feed costs associated with beef production have materialised as a result. Average stocking rate on southern Irish dairy farms is lower (1.80 LU/ha) than it's potential of 2.81 LU/ha (Shalloo and Horan, 2007), indicating an opportunity to utilize the surplus land base for cull dairy cow finishing. Limited research has been undertaken on the effects of pasture based finishing diets. Therefore the profitability of the cull cow finishing enterprise may be significantly increased by raising the inclusion of grazed grass in the finishing diet.

As the majority (90%) of beef produced in Ireland is destined for export, the objective should be to produce lean carcasses of good conformation class suitable for the highest priced markets (Drennan and Keane, 2000). Research to date on predicting optimum finish criteria for cows has been of limited value due to variability (breed, age and animal measurements) between studies (Dolezal et al., 1993). There is merit in the development of predictive equations for cull cow carcass composition using independent variables that are repeatable, non-intrusive and easily measured at farm level. Obvious examples include live weight and BCS.

The objective of this project was to investigate avenues of increasing the value of cull cow beef.

The specific objectives were:

(i) To determine the effect of offering incremental concentrate proportions in the pre-slaughter diet on days to slaughter, average daily gain (ADG), and final live animal, carcass and meat quality characteristics of spring calving cull dairy cows fed to a pre-determined pre-slaughter live weight (LW) and body condition score (BCS).

(ii) To evaluate different over-wintering management strategies prior to finishing at pasture on live performance, carcass and meat quality characteristics of spring calving cull dairy cows fed to a predetermined pre-slaughter LW and BCS.

(iii) To establish the degree of carcass finish of cows slaughtered off Irish farms at the end of the grazing season.

(iv) To develop predictive equations for carcass weight, carcass conformation class and carcass fat class of cull beef and dairy cows, using pre-slaughter live animal measurements.

(v) To create, validate and describe a decision support system (DSS) for cull cow finishing strategies based on data from task (i) and (ii) to determine the; (a) profitability of different cull cow finishing strategies, (b) economically optimum finishing strategy, (c) effect of age of cull cows on profitability, and (d) effect of variation in input and output variables on the stochastically dominant finishing strategy.

3. Experiment I. Effect of Grass Silage and Concentrate Based Finishing Strategies on Cull Dairy Cow Performance, Carcass and Meat Quality Characteristics

The objective of this study was to determine the effect of offering incremental concentrate proportions in the pre-slaughter diet on days to slaughter, average daily gain (ADG), and final live animal, carcass and meat quality characteristics of spring calving cull dairy cows fed to a pre-determined pre-slaughter live weight (LW) and body condition score (BCS).

Animals and experimental design

Sixty-eight Holstein Friesian dairy cows (22% following 1st lactation) were assembled from three Moorepark spring calving herds. The cull cows used on this trial were, on average 279 days (s.d. 6.76) in milk. Cows were culled predominantly for infertility reasons. The experiment was a randomized block design. Dried-off cows were blocked (4 cows per block) according to age [mean, 60 (s.d. 24.3) months], lactation number [mean 3.3 (s.d. 1.93)], Holstein proportion [0.80 (s.d. 0.15)], calving date [25/01/2005 (s.d 96 days], LW (mean of two weeks live weight, recorded pre trial) [605 (s.d. 68.9) kg] and BCS [2.7 (s.d 0.28)], and were randomly assigned to one of four experimental dietary treatments. The control cows were offered ad-libitum grass silage (GS), while the remaining treatments were offered grass silage and concentrate at either 3 (GS+3), 6 (GS+6) or 9 (GS+9) kg DM/cow/day, respectively. The experiment commenced from 17 December 2005 and concluded 27 June 2006 (27 weeks).

Experimental management

Cows were penned according to dietary treatment in a lime dusted concrete cubicle house in four individual herds. All diets were offered using a diet wagon, with concentrate offered as part of a total mixed ration (TMR). Concentrate inclusion was initiated at 3 kg, increasing to 6 and 9 gradually during the ten day drying off period as appropriate. The previous day’s feed refusals were removed, weighed and sub sampled which allowed group intake to be monitored on a continuous basis. The TMR was offered at 115% of the previous days intake for each treatment group. All cows were slaughtered at a commercial beef processing plant (Dawn Meats Charleville, Co. Cork).

Finishing criteria

In order to obtain a maximum carcass value per unit carcass weight, Irish commercial slaughter facilities tend to impose minimum carcass weight, carcass conformation and fat carcass class criteria. In the case of the slaughter facility involved in the current study these criteria were: a minimum cold carcass weight of 272 kg, a minimum carcass conformation class of P+ (a score of 3 on the 15 point scale), and a minimum carcass fat class of 3 (a score of 7 on the 15 point scale). Failure to achieve the desired threshold for cold carcass weight, conformation class or fat class by one increment resulted in a significantly decreased payment. Based on this target the finishing criteria; LW > 620 kg and BCS > 3.5 for each cow were established. As individual cows reached these criteria they were slaughtered. There were eleven slaughter dates in total over the duration of the experiment.

Animal Measurements

Cows were weighed twice weekly, on consecutive days prior to feeding. Live weight was recorded electronically using a portable weighing scales and Winweigh software package (Tru-test Limited, Auckland, New Zealand). The mean weekly LW was used to calculate average daily weight gain (ADG). Body condition score was recorded every 2 weeks (Lowman et al., 1976). Individual dry matter intakes (DMI) were estimated once during the study on week 5, using the n-alkane technique.

Carcass and meat quality measurements

Animals were stunned by captive bolt pistol, hung and bled. The carcasses were graded for conformation on the scale (E, U, R, O, P) and fatness score (1 to 5) which subdivides each class into 3 to give 15 subclasses each for conformation and fat class (Commission of the European Communities, 1982). Carcass conformation and fat score were measured on both sides of each carcass by mechanical grader (Tru-test Limited, Auckland, New Zealand) post-slaughter. Carcass composition and distribution of saleable meat was measured after a 48-h chilling period (4 ^{o}C) where the right side hindquarter of each carcass was boned out to U.K specification.

Individual cuts were weighed, saleable meat, hind and fat proportions were calculated from the carcass dissection results.

A sample of approximately 1 kg was removed from the anterior end of the longissimus dorsi (LD) muscle from each carcass, vacuum packaged and frozen at -20^{o}C. The adhering subcutaneous fat was removed, vacuum packaged and stored prior to colour analysis. Using a band saw (Mainca SM-182, Spain) adhering subcutaneous fat samples were dissected from the frozen LD for colour analysis. The frozen LD was cut into sub samples for colour measurement (2 cm steak), shear force measurement (6 cm steak) and compositional analysis (4 cm steak) and held frozen at -20^{o}C prior to analysis. For fat colour measurement, subcutaneous fat samples were placed on trays, covered with cling film, thawed at 4^{o} C overnight and then allowed to equilibrate to ambient temperature (~20˚C) over a 3-h period. Hunter 'L' (lightness) and 'b' (yellowness) values were recorded using a Minolta CR-300 Chromameter (Minolta Co. Ltd., Osaka, Japan). Six colour measurements (3 on the outer surface and 3 on the inner surface) were made on each fat sample and the mean value of the 6 measurements per cut were used in the statistical analyses. For muscle colour measurements, frozen steaks were placed on plastic trays, covered with cling film, stored at 4^{o} C overnight to bloom. Hunter 'L' and 'a' (redness) values were recorded using the Minolta Chromameter three times at different locations for every steak at day intervals for up to 8 days (Cooke et al., 2004). Shear force analysis of beef samples (n=20) (5 mm x 30 mm x 45 mm), cooked by immersion in a water bath at 80^{o} C for 2 minutes., was conducted using a computer controlled Instron 5544 Universal Testing Machine (Instron Corporation, Buckinghamshire, UK) equipped with a 500-N load cell and a shearing attachment fitted with a 1-mm thick, flat blade. Shear force values were expressed in N/cm^{2} (Cooke et al., 2004). For compositional analysis, steaks were trimmed of visible fat and ground through a plate with 4.5 mm holes. Dry matter, ash, crude protein and crude fat (ether extract) were determined according to the procedures of the 17th edition AOAC (2002). All samples were analysed in duplicate.

Chemical analyses

Grass silage offered was second cut grass silage harvested from a perennial ryegrass sward, which had received 100 kg N/ha eight weeks pre harvest**.** The concentrate composition (fresh weight basis) was 0.33 rolled barley, 0.32 corn gluten, 0.32 citrus pulp and 0.03 dry cow minerals. The chemical composition of the grass silage and concentrate offered is shown in Table 3.1.

Results

Animal performance

Table 3.3 shows the effect of varying dietary treatment on the physical performance of cull dairy cows. Total LW gain over the experiment was 86, 99, 107 and 96 kg for the GS, GS+3, GS+6 and GS+9 treatments, respectively. There was a linear ($P < 0.001$) increase in ADG (kg/day) for the first three dietary treatments, GS (0.71), GS+3 (0.91), GS+6 (1.14) with no additional response to the final increment, GS+9 (1.15). Finishing time decreased linearly ($P < 0.001$) with increasing concentrate inclusion. Cows on the GS+9 treatment (84 days) finished on average 12, 25 and 38 days earlier than those on the GS+6, GS+3, and GS treatments.

Feed intake and total feed utilized

Total dry matter intake was similar across treatments (Table 3.2). The measured concentrate proportions offered were zero, 0.23, 0.41 and 0.56 for the GS, GS+3, GS+6 and GS+9 treatments, respectively. Total concentrate consumed for GS was 0; for GS+3, 0.35, for GS+6, 0.58 and for GS+9, 0.75 tonnes DM/cow. Total grass silage intake for GS was 1.42; GS+3, 1.19, GS+6, 0.86 and GS+9, 0.68 tonnes DM/cow, respectively. As concentrate proportion in the diet increased, silage DM intake decreased linearly ($P < 0.001$). Total DM intake increased linearly ($P < 0.001$) with concentrate level. Total net energy intake (Jarrige, 1989) per day was affected by treatment ($P < 0.001$) and was 10.4 for GS; 11.4 (GS+3), 13.1 (GS+6) and 14.9 (GS+9) (s.e. 0.38) UFL/cow/day, respectively.

Meat Quality

Table 3.4 shows the effect of dietary treatments on muscle composition. Carcass fat lightness (‘L’ value) did not differ ($P > 0.05$) between the four treatments (mean value 70.1). The GS+9 treatment had lower ($P < 0.05$) carcass fat yellowness (‘b’ value) than the GS treatment ($P < 0.02$). The values obtained from the GS+3 and GS+6 treatments were intermediate between the GS and GS+9 treatments. Muscle redness (‘a’ value) decreased over time (8 day period) in all treatments but did not differ (P >

0.05) between treatments. Muscle lightness (‘L’ value) increased over time ($P < 0.001$) in all four treatments leading to a lighter complexion of the meat (mean ‘L’ value 32.9). The ‘L’ value of muscle of the GS and GS+9 differed ($P < 0.001$) from the GS+3 and GS+6.

Discussion

Although days on experiment were different between dietary treatments, the total feed utilized across treatments was similar at 1.45 tonnes DM/cow. Performance in terms of ADG and DMI was similar to dairy cows offered free access to a total mixed ration for similar periods (Garnsworthy, et al., 1987). In the current study the animals receiving the highest increment of concentrate had an ADG of 1.15 kg. Previous studies have shown that Holstein cows finished on a higher energy-dense diet gained up to 1.43 kg/d (Jones and Macleod, 1981). Unlike previous cull cow studies under Irish conditions, the ADG of the GS treatment was satisfactory (0.71 kg). Gleeson and McCarthy (1979) recorded poor ADG response (0.35 kg/cow/day) with cows offered ad libitum grass silage in comparison to the GS treatment in the present study, however this may have been due to the high quality grass silage offered in this experiment.

Wooten et al. (1979) reported that carcass fat cover, marbling and boneless carcass weight increased by feeding a high concentrate diet to cull cows. The results of the present study illustrate that if finishing criteria are set at a given carcass weight, carcass conformation class, carcass fat class, and cows are given the required time to reach the criteria; these differences are nonexistent irrespective of diet offered. Carcass value was not affected by dietary treatments in the present study. Cold carcass weight, carcass grades and carcass dissection yield generally did not differ which is also consistent with the findings of Schnell et al. (1997).

In a review of published studies (Muir et al., 1998) improved lean colour has been associated with increased marbling scores with concentrate fed compared with forage-fed cattle. In the present study there was a significant effect of treatment on muscle lightness but this effect was not consistent with diet ingredients as the GS and GS+9 treatments were significantly different from the GS+3 and GS+6 treatments. The relatively short feeding period may have distorted the expected results which disagree with the findings of Muir et al. (1998) who showed an effect of short-term feeding on lean meat colour, with significant effects of concentrate on *L* (brightness) and *a* (redness) values.

Conclusions

The feed budget required to finish cull dairy cows irrespective of dietary treatment was 1.5 tonnes DM. Offering the lower energy finishing diet, compromised days to slaughter and ADG, however, offering the higher energy diet increased feed budget costs. Young cows have the greatest capability of responding to finishing diets due to superior ADG performance and are likely to be a more viable option for this enterprise. The ability of each individual cow to achieve finishing criteria will determine days to slaughter. Achieving the finishing criteria outlined, irrespective of diet will result in no difference in carcass characteristics, meat composition and meat tenderness, however, ADG, days to slaughter, fat colour and muscle lightness are affected by concentrate inclusion in the diet. The final decision on the nutritional strategy to be employed will be dictated by farm circumstances.

Table 3.1. Mean (s.d) chemical composition and estimated energy values of silage and concentrate offered

	Silage (s.d)	Concentrate (s.d.)

Dry matter (DM) (g/kg)	296 (1.29)	911 (2.9)
pH	3.9 (0.33)	
Crude protein (g/kg DM)	146 (0.86)	124.4 (2.34)
Ammonia (g/kg DM)	87 (1.51)	
ADF (g/kg DM)	320 (2.85)	
NDF (g/kg DM)	546 (5.08)	248 (2.72)
Lactic acid (% total acids)	13.3 (5.70)	
Lactic acid (g/kg DM)	73.5 (11.30)	
DM digestibility (g/kg DM)	742 (5.32)	
Oil (acid hydrolysis) %		2.7 (0.55)
Ash (g/kg DM)		75.5 (1.40)
Crude fibre (g/kg DM)		80.6 (1.18)
UFL (g/kg)	0.82 (0.07)	1.08 (0.05)

ADF, Acid-detergent fibre; NDF, Neutral-detergent fibre; 1 UFL (UFL = Unité Fourragère Lait) is the net energy for lactation equivalent of 1 kg standard air-dry barley. Standard deviations associated with each mean value are presented in parenthesis.

Table 3.2. Estimated dry matter intakes for Holstein-Friesian cull dairy cows offered four grass silage and concentrate based finishing treatments.

	Treatment					Significance		
	GS	GS+3	GS+6	GS+9	Sed	Trt	Lin	Quad
Total Feed Utilized (kg DM/cow)								
Silage	1420	1189	856	679				
Concentrate		344.7	583.3	746				
Total	1420	1533	1439	1425				
Estimated Intake (kg DM/day)								
Silage intake	12.7^a	10.6^b	9.2^c	8.0^d	0.46	***	***	NS
Concentrate intake		3.1	6.2	9.6				
Total dry matter intake (TDMI)	12.7^a	13.7^b	15.4^c	17.6^d	0.46	***	***	0.06
UFL Intake								
Silage (UFL/day)	10.4^a	8.7^a	7.6^b	6.6^b	0.17	***	***	NS
Concentrate (UFL/day)		2.8^a	5.5^b	8.3	0.04	***	***	NS
Total Intake (UFL/day)	10.4^a	11.4^b	13.1^c	14.9^d	0.38	***	***	NS
Group intake								
Silage Intake (kg DM/day/cow)	10.9	10.5	8.9	7.7				
Concentrate Intake		3.1	6.2	9.6				
% Conc. in diet as consumed		22.8	41.1	55.5				

***, P < 0·001; NS, not significant. GS, grass silage; GS+3, grass silage and 3 kg concentrate/day; GS+6, grass silage and 6 kg concentrate/day GS+9, grass silage and 9 kg concentrate/day. Trt, treatment; Lin, linear; Quad, quadratic.

$^{a\text{-}d}$ Means with a different superscript within a row are significantly different (P < 0.05).

Table 3.3. Cow live weight and change, body condition score and change, average daily gain and average days on treatment for Holstein-Friesian cull dairy cows offered, four grass silage and concentrate based finishing treatments.

	Treatment					Significance		
	GS	GS+3	GS+6	GS+9	Sed	Trt	Lin	Quad
Initial live weight (kg)	613	604	601	602	6.65	NS	NS	NS
Slaughter live weight (kg)	699	703	708	698	10.92	NS	NS	NS
Live weight Gain (kg/day)	0.71[a]	0.91[a]	1.14[b]	1.15[b]	0.094	***	***	NS
Period on trial (days)	121.5[a]	108.1[ab]	95.2[bc]	83.5[c]	7.49	***	***	NS
Initial BCS	2.7	2.7	2.6	2.7	0.87	NS	NS	NS
Slaughter BCS	3.49	3.53	3.53	3.52	0.45	NS	NS	NS
BCS Increase	0.83	0.88	0.90	0.84	9.54	NS	NS	NS

***, $P < 0{\cdot}001$;*, $P < 0.05$; NS, not significant. BCS, Body Condition Score. GS, grass silage; GS+3, grass silage and 3 kg concentrate/day GS+6, grass silage and 6 kg concentrate/day; GS+9, grass silage and 9 kg concentrate/day. Trt, treatment; Lin, linear; Quad, quadratic.

[a-d] Means with a different superscript within a row are significantly different ($P < 0.05$).

Table 3.4. Meat composition and quality for Holstein-Friesian cull dairy cows offered four grass silage and concentrate based finishing treatments.

	Treatment					Significance			
	GS	GS+3	GS+6	GS+9	Sed	Trt	Time	Trt*Time	Lin
Protein %	21.0	20.4	20.9	20.7	0.40	NS			NS
Moisture %	71.4	73.0	72.8	72.9	1.03	NS			NS
Ash %	1.4	1.4	1.5	1.3	0.15	NS			NS
Fat %	7.1	5.6	5.5	5.7	1.13	NS			NS
Shear force (N/cm^2)	114	105	112	107	13.0	NS			NS
Fat lightness (L)	69.2	70.6	70.8	69.6	1.45	NS			NS
Fat Yellowness (b)	19.6^{a}	18.6^{ab}	18.8^{ab}	17.5^{b}	0.90	*			*
Muscle lightness (L)	32.2^{a}	33.8^{b}	33.3^{b}	32.1^{a}	0.87	***	***	NS	NS
Muscle Redness (a)	11.5	11.3	11.7	11.0	0.66	NS	***	NS	NS

***, P < 0·001;*, P < 0.05; NS, not significant.

GS, grass silage; GS+3, grass silage and 3 kg concentrate/day; GS+6, grass silage and 6 kg concentrate/day; GS+9, grass silage and 9 kg concentrate/day; Trt, treatment; Time, measured at day intervals for up to 8 days; Lin, linear; Quad, quadratic.

[a-b] Means with a different superscript within a row are significantly different (P < 0.05).

A sub set of ten complete blocks were selected for meat quality analysis, which were randomly selected from the 17 blocks of the experimental design.

Experiment II. An evaluation of over-wintering feeding strategies prior to finishing at pasture for cull dairy cows on live animal, carcass and meat quality characteristics

The objective of this study was to evaluate different over-wintering management strategies prior to finishing at pasture on live performance, carcass and meat quality characteristics of spring calving cull dairy cows fed to a predetermined pre-slaughter LW and BCS.

Materials and Methods

Animals and experimental design

Fifty-six spring calving Holstein-Friesian dairy cows, destined for culling, were randomly assigned to one of four experimental treatments. The experiment commenced on 18th December 2006 and was completed on 29th June 2007. Pre-experimental LW and BCS were 607 (SD = 70.0) kg and 2.75 (SD = 0.38), respectively. The experiment was split into two periods; over wintering period (OWP) and spring finishing period (SFP). Animals were assigned to one of four treatments; A control group (C) was slaughtered after am milking on day 0; and three dietary treatments, two of which were dried pre-experiment and one with the extended lactation concept applied; ad libitum grass silage (GS+G); 75% grass silage and 25% straw (GS+S) and grass silage plus 6 kg concentrate DM/cow/day and milked twice daily (EXTLAC). The OWP lasted 84 days. Subsequent to the OWP cows were turned out to pasture (SFP) until finished for slaughter. All animals were blocked according to age [mean, 68 (SD = 25.6) months], lactation number [mean 3.5 (SD = 2.08)], Holstein proportion [mean 0.75 (SD = 0.25], calving date [13/02/2006 (SD = 70 day)], LW (average of two days live weight, taken on consecutive days) [607 (SD = 70.0) kg] and BCS [2.75 (SD = 0.38)].

Experimental management

OWP: The silage offered was second cut grass silage. The concentrate composition on a fresh weight basis was: 0.47, ground citrus pulp, 0.47, maize gluten, 0.043, vitamin/minerals, and 0.017, fat. During OWP cows were penned according to dietary treatment. All 3 OWP diets were offered once daily at 09.00h and dispensed using a diet wagon (Keenan Engineering Ltd., Borris, Co Carlow, Ireland). Prior to feeding the previous day’s refusals were removed, weighed and sub sampled to allow daily group DM/energy intake to be calculated. Feed was offered at 15% above the previous day's intake for each of the three treatments. Concentrate was offered in the parlour to the EXTLAC treatment in two equal 3 kg DM portions at milking.

SFP: After the initial 84 days OWP, cows from the three treatments were turned out to pasture (12^{th} March 2007) and grazed as a single herd. The sward was a permanent grassland sward which was reseeded the previous year with late heading (*Lolilum perenne* L.) cultivars. Animals were offered approximately 15 kg DM fresh herbage daily, grazing to 4cm post grazing height.

Finishing criteria

As described in Experiment I.

Animal measurements

Estimated individual DM intakes (DMI) using the n-alkane technique were measured during week 7 of OWP and week 3 of SFP (trial week 15). Sward measurements were recorded daily as described by McEvoy et al. (2007). Cows were stocked at a rate of 1.44 cows/ha. Total feed utilisation was calculated for SFP by multiplying the group DM intakes by the number of days on SFP. All live animal, carcass and meat quality characteristics were measured as in Experiment I.

Chemical analyses

The chemical composition of the grass silage, straw, concentrate and herbage offered is shown in Table 4.1. Representative silage, straw and concentrate samples were collected three times weekly during OWP. Samples were stored at -20 ºC before being freeze dried and milled through a 1 mm sieve before chemical analysis. Proximate analysis of grass silage, straw and concentrate samples was completed as described in Experiment I.

Results

Live performance

Table 4.2 shows the effects of the imposed treatments on live animal performance during the subsequent SFP. During OWP, ADG significantly ($P < 0.001$) differed between treatments; GS+G (+ 0.89 kg/day) GS+S (+ 0.53 kg/day) and EXTLAC (-0.03 kg/day). BCS (end of OWP) was also different ($P < 0.01$) between treatments;

GS+G (3.4), GS+S (3.1) and EXTLAC (3.0). Mean (SD) LW 87.6 (32.54) and BCS 0.80 (1.01) increased over the total trial period. During SFP period, the GS+S (0.96 kg/day) and EXTLAC (0.91 kg/day) treatments achieved greater ADG than the GS+G (0.62 kg/day) treatment. Total period ADG was lower ($P < 0.001$) for the EXTLAC (0.44) treatment compared with the two other dietary treatments, GS+S (0.71) and GS+G (0.81) kg/day. As a consequence of this, days on trial were different between treatments. The GS+G treatment had 38 and 33 ($P < 0.001$) less days on trial than the GS+S and EXTLAC treatments. The EXTLAC treatment had a mean milk yield of 16.4 (SD = 3.51) kg milk/cow day, 40.9 (SD = 5.59) g/kg fat, 35.0 (SD = 3.00) g/kg protein) and 43.6 (SD = 1.26) g/kg lactose over a 77 day lactating period.

Feed intake measurements

Table 4.3 shows estimated group intake as well as estimated individual intake during both experimental periods. During OWP individual DM intake and UFL intake was significantly greater ($P < 0.001$) for the EXTLAC treatment compared to the other two dietary treatments. Energy balance did not differ between treatments during OWP or SFP. Diet UFL concentration for the EXTLAC was 0.32 and 0.30 greater than the GS+S and the GS+G treatments, respectively. There was no difference in individual DM and UFL intake between treatments during SFP.

Total feed utilized over the experiment was lowest for the GS+G treatment (1.9), GS+S (0.1) and EXTLAC (+ 0.6) treatments. Reflecting the total feed utilized, differences ($P < 0.001$) between the GS+G (1455 UFL), GS+S (+ 529 UFL) and EXTLAC (945 UFL) treatments were measured.

Grazing management

Pre-grazing sward height was 14.3 (SD = 5.54) cm and daily herbage mass was 2812 (SD = 1683.9) kg DM/ha. Daily herbage allowance allocated was 15.2 (SD = 5.31) kg DM/cow day; mean post-grazing sward height was 5.2 (SD = 1.26) cm/day, the pre and post grazing measurements equated to 91 (SD = 15.0) % grass utilization.

Carcass and meat quality characteristics

Mean values for slaughter carcass traits for the three treatments and C group are shown in Table 4.4. Carcass conformation class ($P < 0.01$) and carcass fat class increased ($P < 0.001$) for all treatments relative to the C group. Mean carcass weight

(+ 72.3 kg), saleable hind carcass meat (+ 17.4 kg) and kill-out proportion (+ 0.04) were greater ($P < 0.001$) for all three treatments compared with the C group.
Individual carcass cut yield were improved ($P < 0.001$) compared with the C group for treatments offered a finishing diet. On average, saleable meat yield increased by 27% compared to having no finishing treatment.
Table 4.5 shows the effect of dietary treatments on muscle composition and quality. Muscle lightness (‘L’ value) increased over time ($P < 0.001$) in all four treatments leading to a lighter complexion of the muscle. The three dietary treatments had greater ($P < 0.001$) muscle redness (‘a’ value) and lightness (‘L’ value) compared to the C group. Muscle redness (‘a’ value) decreased over time in all treatments. Intramuscular fat percent increased ($P < 0.001$) from 2.1 (C) to 3.5 (mean value for three dietary treatments) when offered a finishing diet (1.4 %). Analysis of variance showed an effect of both time ($P < 0.001$) and diet ($P < 0.01$) on hue angle values (H°). Time of display and diet affected ($P < 0.001$) chroma values.

Discussion

Live performance

Cows (GS+G) offered a consistent energy supply over the duration of the trial, achieved steady increases in ADG and BCS. Cows offered a restricted diet (GS+S) in terms of dietary energy had constrained performance (ADG) during the OWP, the EXTLAC treatment recorded no bodyweight increase during the lactating period. Experiment I reported ADG of 0.71 kg/cow for cull cows offered grass silage for the entire fattening period while in this study the performance of the GS+G treatment improved from the previous study (0.89 kg/day) as a result of turnout to pasture. Gleeson and McCarthy (1979) recorded ADG response (0.35 kg/cow/day) for cows offered ad libitum grass silage. The greater performance achieved in Experiment I and II can be attributed to offering greater quality grass silage in comparison to Gleeson and McCarthy (1979). The silage quality offered here was superior to that typically offered at farm level {DMD 667 g/kg DM} in Ireland, (Keating and O’Kiely et al. 1997). The objective of the GS+S treatment was to reflect the performance achievable when offering grass silage of national level standard (hence the straw inclusion) and subsequent lower ADG.
At grass the GS+S and EXTLAC treatments in particular expressed high levels of compensatory growth; mean ADG was 0.93 kg compared with GS+G at 0.62 kg.

Thus, carcass and lean tissue repletion increased at a greater rate for previously undernourished cows during the OWP when turned out to pasture. When fattening cull cows at pasture a realistic ADG objective should be 1.0 kg ADG for each day at grass.

Even though the EXTLAC treatment had greatest TDMI (17.9 kg DM/cow) they recorded lowest energy balance during the OWP. Both the GS+G and GS+S treatments had lower TDMI but positive energy balances. Cull cows generally obtain greater positive energy balances due to lower levels of ADG relative to growing steers (Drennan et al., 2000). During the SFP no difference was recorded for TDMI, however energy balance increased substantially for all treatments. Such a result is not surprising given that all cows were dry and gaining weight, and had no other metabolic demand.

Duration of feeding

Feeding duration was determined by the speed at which individual cows achieved the pre slaughter target LW and BCS. Previous studies have focussed on finishing animals to specific time points. Wooten et al. (1979) slaughtered cull beef cows at specified levels of condition. Wooten's study resulted in varying feeding period of 38, 63 and 108 days, offered 0.80 concentrate diets. Large differences in the duration (days) of the finishing period resulted between the treatments 115 (GS+G), 148 (GS+S) and 153 (EXTLAC). Swingle et al. (1979) showed that the energy density of the diet offered (ingredient or quantity) was not a limiting factor in achieving pre-defined slaughter criteria, however it did impact on days to slaughter. Experiment I reported a linear inverse relationship between dietary concentrate inclusion rate (0 to 9 kg) and duration of the finishing period in cull dairy cows.

Carcass and meat quality characteristics

Table 4.5 shows that all carcass quality characteristics were improved by finish feeding. Carcass weight is the principal defining factor for carcass value in a cull cow enterprise. Cold carcass weight increased by 0.22 when finishing diets were offered. Vestergaard et al. (2007) all found cold carcass weight increases ranging from 0.17 to 0.26 when finishing diets were offered compared with non finishing strategies. Carcass weight increases mirrored the kill-out proportions of each finishing treatment (mean, 0.46) compared with the C group (0.42).

Variation in muscle colour and lightness is affected by factors such as age, exercise and diet (Livingston & Brown, 1981). Significant differences were recorded in muscle redness between finishing treatments and the C group in the present study. This indicates that muscle redness is affected by the level of finish at slaughter. Pre-slaughter stress (C group) can lead to depletion of muscle glycogen, an abnormally high standard of dark-cutting beef. This stress could have been manifested in the C group as they were slaughtered at low BCS (2.79) at the immediate end of lactation. Mechanical measures of tenderness (Warner-Bratzler shear force) were not different between treatments. When shear force required to cut cull cow muscle (139 N/cm^2) is compared to shear force required to cut muscle from younger animals (Cooke et al., 2004; continental cross heifers (63.2 N/cm^2)) approximately double the force was required. This contributes to some of the difference in eating quality between young and older animals and thus the price difference between the two sources of beef.

Conclusions

Restricting cows in the finishing period either by including straw in the diet or milking the cows over the winter delayed subsequent days to slaughter by 35 days. Over the entire period, daily LW gain was lower for the EXTLAC (0.44) treatment compared with the two other dietary treatments, GS+G (0.81) kg/day and GS+S (0.71), respectively. Restricting diet energy encouraged a high level of compensatory growth at pasture. Given the results of this study a target ADG of 0.9-1.0 kg/d at pasture seems possible. Cold carcass weight increased by 0.22 when finishing diets were offered. Significant differences occurred for muscle redness between finishing treatments and the C group indicating that muscle redness is affected by the level of finish at slaughter.

Table 4.1. Mean (s.d) chemical composition and estimated energy values of grass silage, concentrate, straw (OWP) and grass (SFP) offered to Holstein-Friesian cull dairy cows.

	Silage (s.d)	Straw (s.d)	Concentrate (s.d.)	Grass (s.d)
Dry matter (DM) (g/kg)	318 (5.15)	912 (1.90)	917 (2.04)	211 (3.39)
pH	4.2 (0.39)			
OM Digestibility (g/kg/DM)				747 (67.65)
Crude protein (g/kg/DM)	167 (8.14)	57.8 (6.69)	175 (13.55)	179 (47.27)
ADF (g/kg/DM)	345 (18.99)	506 (21.11)		254 (36.89)
NDF (g/kg/DM)	530 (21.91)	799 (15.05)	256 (37.32)	466 (59.32)
Lactic acid (g/kg/DM)	260 (11.81)			
DM digestibility (g/kg/DM)	701 (5.20)			
Ash (g/kg/DM)	822 (5.09)	498 (6.98)	969 (14.39)	862 (23.72)
Crude fiber (g/kg/DM)			864 (15.94)	
UFL (g/kg)	0.78	0.44	1.06	1.08

ADF, Acid-detergent fiber; NDF, Neutral-detergent fiber; 1 UFL (UFL = Unité Fourragère Lait) is the net energy for lactation equivalent of 1 kg standard air-dry barley. Standard deviations associated with each mean value are presented in parenthesis.

Table 4.2. Cow live weight, body condition score, average daily gain, days on treatment and change for Holstein-Friesian cull dairy cows offered four finishing strategies.

	Dietary treatment				Significance	
OWP	C	GS	GS+S	EXTLAC	Sed	Trt
Initial Live weight (kg)		604	609	620	15.03	NS
End Live weight (kg)		674[a]	653[a]	619[b]	17.24	**
Average Daily Gain (kg/day)		0.89[b]	0.53[a]	-0.03[c]	0.11	***
Days on trial		81	84	84	1.49	NS
Initial BCS		2.82	2.61	2.79	0.011	NS
End BCS		3.41[b]	3.13[a]	2.98[a]	0.098	**
SFP						
Initial Live weight (kg)		674[a]	653[a]	619[b]	17.24	NS
Slaughter Live weight (kg)		695	714	685	17.02	NS
Average Daily Gain (kg/day)		0.62[b]	0.96[a]	0.91[a]	0.16	*
Days on trial		34[a]	64[ab]	73[b]	7.24	*
Initial BCS		3.41[b]	3.13[a]	2.98[a]	0.098	**
Slaughter BCS		3.59[c]	3.52[b]	3.50[b]	0.035	*
BCS Average Daily Gain		0.004	0.006	0.008	0.001	NS
Total Period						
Initial Live weight (kg)	599	604	609	620	15.03	NS
Slaughter Live weight (kg)	599[a]	695[b]	714[b]	685[b]	17.35	***
Average Daily Gain (kg/day)	N/A	0.81[a]	0.71[a]	0.44[b]	0.15	*
Period on trial (days)	0[a]	115[c]	148[b]	153[b]	8.55	***
Initial BCS	2.79	2.82	2.61	2.79	0.116	NS
Slaughter BCS	2.79[a]	3.59[c]	3.52[b]	3.50[b]	6.33	***

[a–c] Means with a different superscript within a row are significantly different ($P < 0.05$).

C, slaughtered on Day 0; GS, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 kg concentrate/day.

Trt, treatment; OWP, over wintering period (12 weeks). SFP, spring finishing period; BCS, body condition score.

*, P<0.05; **, P<0.01;***, P < 0·001; NS, not significant.

Table 4.3. Estimated intakes and energy balances during indoor and outdoor periods for Holstein-Friesian cull dairy cows offered three finishing strategies.

	Treatment			Significance	
(cow/day)	GS	GS+S	EXTLAC	Sed	Trt
OWP					
Total Feed Utilized (kg/DM/cow)	1223	1092	1492		
Total Daily mean Intake (kg/DMI)	14.6	13.0	18.2		
Estimated Intake (TDMI)	14.4[a]	15.3[a]	17.9[b]	0.60	***
Estimated UFL Intake (UFL)	11.2[a]	10.8[a]	15.9[b]	0.47	***
Energy Balance (UFL)	1.8	2.7	1.4	0.60	NS
SFP					
Total Herbage Utilized (kg/DM/cow)	719	914	1006		
Estimated intake (TDMI) (kg/DM)	14.5	15.3	14.8	0.82	NS
Estimated UFL Intake (UFL)	15.7	16.5	15.9	0.88	NS
Energy Balance (UFL)	7.5	6.5	5.2	1.16	NS
Total Period (OWP + SFP)					
Total feed utilized (kg/cow)	1941	2006	2498		
Total UFL intake (UFL/cow)	1455[b]	1984[a]	2400[c]	154.9	***
Total Energy Balance (UFL/cow)	374.7[a]	642.4[b]	457.5[ab]	93.93	*

[a–c] Means with a different superscript within a row are significantly different (P < 0.05).

GS, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 kg concentrate/day.

Trt, treatment; OWP, over wintering period (12 weeks). SFP, spring finishing period.

*, *P*<0.05; ***, P < 0·001; NS, not significant.

Table 4.4. Least square means for slaughter and carcass traits for Holstein-Friesian cull dairy cows offered four finishing strategies.

	Dietary treatment				Significance	
	C	GS	GS+S	EXTLAC	Sed	Trt
[1]Carcass conformation (Slaughter)	1.92[a]	3.36[b]	3.00[b]	3.29[b]	0.35	**
[2]Carcass fat score (Slaughter)	2.86[a]	7.86[b]	7.36[b]	7.43[b]	0.69	***
Carcass weight (kg)	251[a]	322[b]	329[b]	319[b]	8.38	***
Side carcass weight (kg)	129[a]	165[b]	168[b]	162[b]	4.48	***
Saleable meat of hind carcass (kg)	45.4[a]	63.4[b]	63.6[b]	61.5[b]	1.49	***
Saleable meat proportion	0.71[a]	0.75[b]	0.75[b]	0.75[b]	0.01	***
Hindquarter proportion of side	0.50	0.51	0.50	0.51	0.01	NS
Kill out proportion	0.42[a]	0.46[b]	0.46[b]	0.47[b]	0.01	***
Kidney channel fat proportion	0.02[a]	0.03[b]	0.04[b]	0.03[b]	0.003	***
pH	N/A	5.69	5.64	5.66	0.06	NS

[a–b] Means with a different superscript within a row are significantly different (P < 0.05).

C, slaughtered on Day 0; GS, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 kg concentrate/day.

[1]Scale 1 to 15 (15 = best conformation; EUROP conformation scale); [2]Scale 1 to 15 (15 = fattest).

Trt, treatment; OWP, over wintering period (12 weeks). SFP, spring finishing period.

*, *P*<0.05; **, *P*<0.01;***, P < 0·001; NS, not significant.

Table 4.5. Least square means for meat composition and quality for Holstein-Friesian cull dairy cows offered four finishing strategies.

	Dietary treatment					Significance		
	C	GS	GS+S	EXTLAC	Sed	Trt	Time	Trt*Time
Protein %	20.5	20.3	19.3	20.6	0.86	NS		
Moisture %	75.5	74.5	74.7	74.8	0.42	NS		
Ash %	1.8	1.8	1.8	1.6	0.26	NS		
Fat %	2.1[a]	3.6[b]	3.4[b]	3.6[b]	0.30	***		
Shear force (N/cm^2)	144	132	134	144	8.6	NS		
Fat lightness (L)	67.4	69.9	68.0	67.6	1.83	NS		
Fat Yellowness (b)	21.9	22.8	24.5	22.9	2.57	NS		
Muscle lightness (L)	36.4	37.2	38.4	37.4	0.67	NS	***	NS
Muscle Redness (a)	11.7[a]	14.2[b]	13.6[b]	14.3[b]	0.50	***	***	NS
Chroma (C*)	13.7[a]	16.0[b]	15.7[b]	16.1 [b]	1.28	***	***	NS
Hue angle (H°)	31.5[a]	27.7[b]	30.1[a]	28.0[b]	3.51	**	***	NS

[a–b] Means with a different superscript within a row are significantly different ($P < 0.05$).

C, slaughtered on Day 0; GS, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 kg concentrate/day.

Trt, treatment; OWP, over wintering period (12 weeks). SFP, spring finishing period. Time, measured at day intervals for up to 8 days; Lin, linear; Quad, quadratic.

A sub set of 8 complete blocks were selected for meat quality analysis, which were randomly selected from the 14 blocks of the experimental design. **, $P<0.01$;***, $P < 0·001$; NS, not significant.

Experiment III. Prediction of Cull Cow Carcass Characteristics from Live Weight and Body Condition Score Measured Pre Slaughter

This study had two objectives;

(i) to establish the degree of carcass finish of cows slaughtered off Irish farms at the end of the grazing season.

(ii) to develop predictive equations for carcass weight, carcass conformation class and carcass fat class of cull beef and dairy cows, using pre-slaughter live animal measurements.

Materials and Methods

Experimental approach

Data used in this study were obtained from 2,163 cows measured in an Irish commercial slaughter facility between September and November, 2005. Live weight and BCS were recorded on cows entering the slaughter facility by the same trained evaluator during 25 visits. LW was recorded electronically, using portable weighing scales and the Winweigh software package. Body condition scores were assessed using a five point linear scale (1 = emaciated, 5 = extremely fat) with increments of 0.25. These measurements were recorded in a restraining compartment prior to the slaughter crate. Cows were identified by their unique national identification number (DAF, 2006). Details pertaining to animal identification, herd number, breed, birth date and slaughter date were obtained from the Irish cattle movement monitoring system (CMMS, 2006) for each cow recorded.

Carcass traits

Carcass data were collected after slaughter, including hot and cold carcass weights (left and right sides), carcass conformation class and carcass fat class. Kill-out proportion was calculated as the ratio of cold carcass weight to pre-slaughter LW. Carcass conformation and fat classes were assessed, according to the EU Beef Carcass Classification Scheme (Commission of the European Communities, 1982). Each of the 5 classes was sub divided into 3 and each sub class was awarded a number on a 1 to 15 scale (15 = best conformation class and highest fat class).

Data editing

Based on data availability, the data set was divided into three breed categories for analysis: cows sired by Holstein/Friesian (FR), cows sired by early maturing beef breeds including Hereford, Angus and Shorthorn (EM); and cows sired by late maturing beef breeds including Charolais, Limousin, Simmental and Belgian Blue (LM). No attempt was made to differentiate between purebred and crossbred cows, however the vast majority of the beef breed categories were crossbred, reflecting the Irish national cattle population.

In order to obtain a maximum carcass value per unit carcass weight, Irish commercial slaughter facilities tend to impose minimum carcass weight, carcass conformation and fat carcass class criteria. In the case of the slaughter facility involved in the current study these criteria were: a minimum cold carcass weight of 272 kg, a minimum carcass conformation class of P+ (a score of 3 on the 15 point scale), and a minimum carcass fat class of 3 (a score of 7 on the 15 point scale). Failing to achieve the desired threshold for all three criteria simultaneously resulted in a €0.42/kg reduction in carcass value irrespective of by how much they failed (DAF, 2006). A binary trait, denoted as TARGET was created to reflect the success or failure of each cow in the dataset in meeting the above carcass criteria.

Results

Data set profile

The frequency of individual breeds within the various breed categories are presented in Table 5.1. The FR, EM and LM categories accounted for 67, 15 and 18 % of the total, respectively. Least square mean estimates for live and carcass measurements together with orthogonal comparisons are shown in Table 5.2. Age at slaughter did not differ significantly amongst the breed categories. On average, cold carcass weight was above the desired threshold of 272 kg for all breed categories. The cows in the FR category, on average, were slaughtered below the desired carcass fat class of 7 (-1.2 units on the 15 point scale) and were also marginally short of the desired carcass conformation class of 3 (-0.1 on the 15 point scale). On average both of the beef categories were slaughtered at sufficient weight, carcass conformation and carcass fat to obtain the TARGET carcass value. The TARGET carcass was achieved by 22%, 47% and 53% of the FR, EM and LM categories, respectively.

Compared to the FR, the BEEF cows were slaughtered at a lower LW ($P<0.05$) and higher BCS ($P<0.001$). The beef breeds achieved higher cold carcass weights ($P<0.001$), higher carcass conformation class ($P<0.001$), higher carcass fat class ($P<0.001$) and higher kill-out proportion ($P<0.001$) compared to FR. The proportion of cows achieving the TARGET carcass criteria was also higher ($P<0.001$) for the BEEF categories compared to FR. A comparison of the two beef categories shows, that on average, the LM breeds were slaughtered at heavier LW (591 kg v. 564 kg; $P<0.001$). Cold carcass weight (301 kg v. 278 kg), carcass conformation class (4.9 v. 4.3) and kill-out proportion (0.51 v. 0.49) were higher ($P<0.001$) for the LM than the EM, while carcass fat class (8.3 v. 7.4) was higher ($P<0.05$) for the EM than the LM. No difference ($P=0.099$) in the TARGET carcass was observed between the EM and LM categories.

Influence of LW and BCS on TARGET carcass

As both LW and BCS increased, the proportion of cows meeting the TARGET carcass tended to increase for all categories. Only 2% of cows slaughtered at low LW (<550 kg) and low BCS (<3.00) achieved the TARGET carcass specification. Approximately 40% of FR cows slaughtered at LW over 550 kg with a BCS of 3.5 or greater achieved the TARGET carcass, while a high proportion (over 90%) of cows in the EM and LM categories slaughtered at the same weight and BCS achieved the TARGET carcass.

Prediction equations

The "best" prediction equations for carcass weight, carcass conformation class, carcass fat class and TARGET carcass for each of the three breed categories are presented in Tables 5.3, 5.4, 5.5 and 5.6, respectively. For cold carcass weight both LW and BCS were significant for all breed categories and the highest coefficients of determination were obtained when these were included in the models. LW was not a significant predictor of carcass conformation class or carcass fat class for any of the breed categories and BCS was not significant for FR. Body Condition Score contributed significantly to the prediction of carcass conformation class (R^2 0.43 and 0.49) and carcass fat class (R^2 0.59 and 0.65) for both EM and LM (Tables 5.4 and 5.5). Both LW and BCS contributed significantly to the prediction of TARGET carcass for all three breed categories (Table 5.6.), but the coefficient of determination of the prediction equation for FR was considerably lower than for the two beef breed categories. The prediction equations for carcass fat class, carcass conformation and TARGET carcass had moderate R^2 values (0.43 and 0.69) for both beef breed categories.

Equation Validation

Fig. 5.1 shows the plotted regression line, for actual and predicted cold carcass weight using cull dairy cow live and slaughter records (n=124), used by Minchin et al. (2009a,b) to validate the prediction equation for FR. The high coefficient of determination indicates that the equation predicted cold carcass weight for the independent data set with a mean (se) bias of +18 kg (1.14). The accuracy of prediction was estimated to be 0.89. The root mean squared error value obtained was 12.56. The correlation between the observed carcass weights and the residuals was not different from zero signifying that the observed bias exhibited a consistent trend across the entire validation data set.

Discussion

It is clear from the data presented that the practice of finishing cull cows is not consistent across dairy and beef herds. Cows are being presented at the factory with carcasses that range from grossly under-finished to exceptionally well-finished. This study shows that a minority of cows slaughtered during the late September to late November period achieved the desired carcass characteristics that merit maximum value per kg carcass weight. The proportion of the culled dairy cows meeting the TARGET carcass criteria was 22%, while that for the beef (EM and LM) cows averaged 50%. In the case of the FR cows, it can be assumed that at least 55% of cull cows did not receive any form of finishing regimen prior to slaughter based on their pre-slaughter BCS of 3 or less. On the other hand, it is plausible to suggest that approximately 25% (slaughtered at a BCS of 3.5 or greater) were subjected to some form of finishing strategy. Of the latter, however, only 40% managed to achieve the TARGET, suggesting either a limitation on the part of FR sired animals to achieve the TARGET, or that the degree of finish achieved was insufficient. Nevertheless, FR sired cattle are inferior to those sired by beef breeds with respect to carcass conformation (Keane, 1994; Keane, 2003; Keane, & Drennan, 2008). The current data reveal that of the dairy cows slaughtered at a BCS of 3.5 and failing to achieve the

TARGET carcass, more than 60% failed to achieve the desired carcass conformation class. Beef breed comparisons generally show that the late-maturing European continental breed types have superior carcass conformation class, kill-out proportion and a higher muscle to fat ratio compared to early-maturing breed types (Keane, & Drennan, 2008). In the present study, the LM cows were superior to EM cows for cold carcass weight, carcass conformation class and kill-out proportion, and had a lower carcass fat class. This finding is common among beef breed comparisons. Animals in the EM category mature at a lower LW, have smaller skeletal size and require a shorter finishing period (Keane & Drennan, 2008). Despite being easier to finish, it appears that at least 36% of beef sired cull cows in the present study received no particular finishing treatment prior to slaughter based on their pre-slaughter BCS of 3 or less.

Prediction equations

The traits used in the prediction equations (LW and BCS) were simple, accurate and non-invasive indicators of carcass weight, but they were less accurate indicators of carcass classification. Another Irish study which recently examined the relationship between muscular and skeletal scores recorded on live animals with carcass composition and value in steers and heifers concluded that live animal muscular scores are useful indicators of carcass meat proportion and value (Drennan et al., 2008). The current study illustrates that LW and BCS vary in their usefulness for the prediction of cold carcass weight, carcass conformation class, carcass fat class and TARGET carcass. While, the capability to predict cold carcass weight from LW and BCS was consistent regardless of breed category, the prediction equations for carcass conformation class, carcass fat class and TARGET carcass provided moderate to poor outcomes, so in essence are deemed not to be useful in practice.

With regard to the validation exercise, a high accuracy of prediction was obtained, and while the results showed that the equation over-estimated cold carcass weight by on average 18 kg this bias was found to be a consistent effect. This represents an over-estimation of approximately 5% from the observed carcass values. This difference can be attributed to LW losses associated with transport to the slaughter facility. The animals used for the validation data set (Minchin et al., 2009a, 2009b) were weighed at the Moorepark Research Centre prior to being transported to slaughter. Transport from farm gate to slaughter facility can be a confounding issue, due to gut fill losses during transport. Furthermore, animals are commonly held for a variable period without feed in the lairage at the abattoir prior to slaughter. Gutfill loss can amount to approximately 7% of LW depending on trip duration and hours to slaughter from final feeding. It is important that this differential is taken into consideration when using the current equation in commercial practice. The coefficients of determination obtained for the prediction of carcass conformation class, carcass fat class and TARGET carcass were not satisfactory and therefore validation was not considered worthwhile. Data were not available to validate the beef category equations, so additional research is required to validate these using an independent test population.

Fundamental to the philosophy portrayed in the current study is that the decision support tool (equation) developed be easily applied at farm level. One potential drawback is the fact that weighing scales are not routinely available on Irish commercial beef farms. Heart girth has been shown previously to be strongly correlated with LW. This may need validation, but would offer improved applicability at commercial farm level.

Conclusions

A high proportion of cull dairy and beef cows are under-finished at slaughter. Carcass characteristics vary with breed category. Easily measured pre slaughter traits such as LW and BCS vary in their usefulness as predictors of carcass weight, carcass conformation class and carcass fat class. Live weight and BCS are useful predictors of cold carcass weight but are of limited value for prediction of conformation class and fat class. Research to validate current cull cow pricing systems based on meat yield and value is warranted.

Table 5.1. Representative numbers (n) within breed categories of the total data set.

Breeds	**n**	**Percent of Total**
Dairy (n=1441)		
Holstein/Friesian	1441	66.6
British beef (n=336)		
Angus	80	3.7
Hereford	218	10.1
Shorthorn	38	1.8
Continental beef (n=386)		
Belgian Blue	32	1.5
Charolais	131	6.1
Limousin	127	5.9
Simmental	96	4.4

Table 5.2. Least square mean values (standard error) for live and carcass measurements of cull cows together with orthogonal contrasts.

Variable	FR	EM	LM	FR v BEEF	EM v LM
Age at slaughter (months)	98 (0.7)	102 (1.4)	100 (1.3)	NS	NS
Live weight (kg)	587 (2.2)	564 (4.6)	591 (4.2)	*	***
Body condition score (1-5)	3.0 (0.01)	3.3 (0.03)	3.3 (0.03)	***	NS
Cold carcass weight (kg)	277 (1.4)	278 (2.9)	301 (2.6)	***	***
Carcass conformation class[1]	2.9 (0.04)	4.3 (0.09)	4.9 (0.08)	***	***
Carcass fat class[2]	5.8 (0.09)	8.3 (0.18)	7.4 (0.16)	***	**
Kill-out proportion	0.47 (0.01)	0.49 (0.03)	0.51 (0.03)	***	***
TARGET carcass[3]	0.22 (0.01)	0.47 (0.02)	0.53 (0.02)	***	0.01

*, $P<0.05$; **, $P < 0.01$; ***, $P < 0{\cdot}001$; NS, not significant.

FR sired by Holstein-Friesian breed; EM sired by early maturing beef breeds; LM sired by late maturing beef breeds.

[1]Scale 1 to 15 (15 = best conformation; EUROP conformation scale); [2]Scale 1 to 15 (15 = fattest);

[3]Proportion of cows achieving criteria required for the TARGET carcass (carcass weight >271 kg; carcass conformation class >2; carcass fat class >6).

Table 5.3. Multiple regression prediction equations for cold carcass weight for 3 breed categories.

Breed	Intercept		Live weight (kg)		BCS	[1]Root MSE	R^2
FR	Y= -48.89	+	0.34	+	41.90	22.21	0.81
Significance	***		***		***		
EM	Y= -71.80	+	0.38	+	40.72	21.49	0.85
Significance	***		***		***		
LM	Y= -74.56	+	0.41	+	40.38	26.57	0.79
Significance	***		***		***		

***, P < 0·001; FR sired by Holstein-Friesian breed; EM sired by early maturing beef breeds; LM sired by late maturing beef breeds. BCS, body condition score (scale 1-5). [1]Root mean square error.

Table 5.4. Multiple regression prediction equations for carcass conformation class for three breed categories.

Breed	Intercept		BCS	[1]Root MSE	R^2
FR	Y= 2.94	+	0.04	1.49	0.0002
Significance	***		NS		
EM	Y= -2.79	+	2.14	1.16	0.49
Significance	***		***		
LM	Y= -3.33	+	2.50	1.42	0.43
Significance	***		***		

*, P < 0.05; ***, P < 0·001; NS, not significant; FR sired by Holstein-Friesian breed; EM sired by British beef breeds; LM sired by continental beef breeds; BCS, body condition score (scale 1-5). [1]Root mean square error.

Table 5.5. Multiple regression prediction equations for carcass fat class for three breed categories

Breed		Intercept		BCS	[1]Root MSE	R^2
FR	Y=	5.44	+	0.11	3.21	0.0003
Significance		***		NS		
EM	Y=	-8.70	+	5.12	1.98	0.65
Significance		***		***		
LM	Y=	-9.60	+	5.16	2.10	0.59
Significance		***		***		

***, P < 0·001; NS, not significant; FR sired by Holstein-Friesian breed; EM sired by British beef breeds; LM sired by continental beef breeds; BCS, body condition score (scale 1-5). [1]Root mean square error.

Table 5.6. Multiple regression prediction equations for proportion achieving TARGET[2] carcass for three breed categories.

Breed		Intercept		Live weight (kg)		BCS	[1]Root MSE	R^2
FR	Y=	-0.91	+	0.001	+	0.18	0.39	0.15
Significance		***		***		***		
EM	Y=	-1.99	+	0.002	+	0.48	0.35	0.52
Significance		***		***		***		
LM	Y=	-2.02	+	0.002	+	0.45	0.36	0.48
Significance		***		***		***		

***, P < 0·001; NS, not significant; FR sired by Holstein-Friesian breed; EM sired by British beef breeds; LM sired by continental beef breeds; BCS, body condition score (scale 1-5). [1]Root mean square error, [2]TARGET carcass, carcass weight, >271 kg; carcass conformation class, >2; fat class, >6.

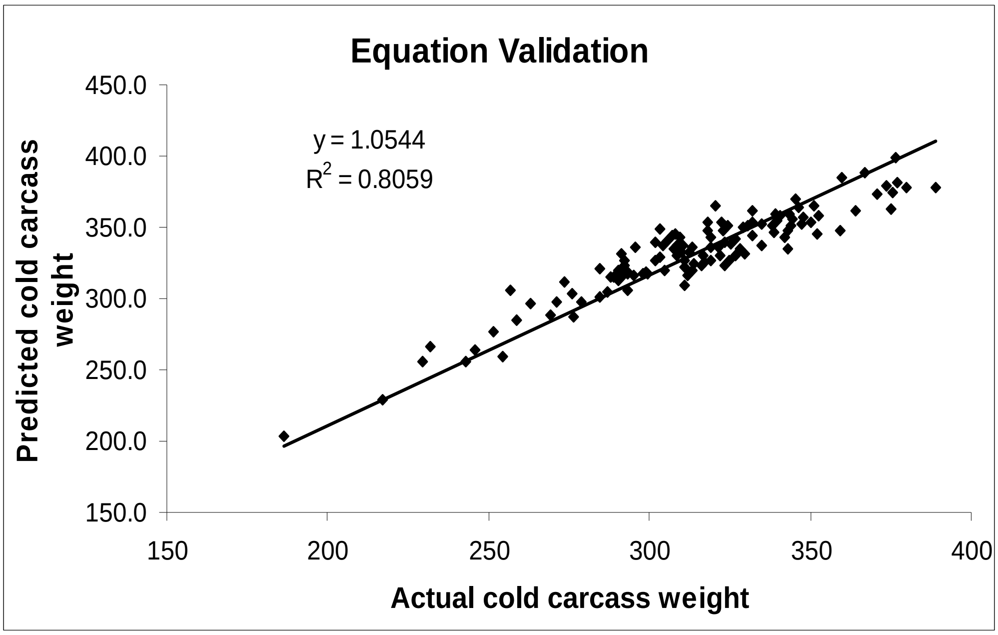

Fig. 5.1. Validation of the cold carcass weight prediction model using data (n=124) from slaughtered cull dairy cows. Equation used to predict cold carcass weight (Y) from live animal measurements; Y = -48.88861+0.34303(LWT) +0.41897(BCS).

Experiment IV. Development of a decision support (DSS) tool to evaluate the financial implications of cull cow finishing under different feeding strategies

The objective of this study was to create, validate and describe a decision support system (DSS) for cull cow finishing strategies based on data from task (i) and (ii) to determine the; (a) profitability of different cull cow finishing strategies, (b) economically optimum finishing strategy, (c) effect of age of cull cows on profitability, and (d) effect of variation in input and output variables on the stochastically dominant finishing strategy.

Materials and Methods

Production study details

The data for the DSS is based on a study which evaluated seven finishing strategies across two separate experimental years and reported by Minchin et al. (2009a,b).

Year (1): Sixty-eight spring calving Holstein-Friesian dairy cows on lactation completion were randomly assigned to four feeding strategies (FS): ad-lib grass silage (GS), GS + 3 kg concentrate (GS+3), GS + 6 kg concentrate (GS+6) and GS + 9 kg concentrate (GS+9). Results are outlined in Experiment I.

Year (2): Fifty-six spring calving Holstein-Friesian dairy cows were randomly assigned to four experimental FS. The experiment was split into 2 periods; over wintering period (OWP) and spring finishing period (SFP). The FS were; A control group (C) slaughtered after am milking on d 0; and three dietary strategies, two of which were dried off pre-experiment and one with the extended lactation concept applied; ad libitum grass silage (GS+G); 0.75 grass silage and 0.25 straw (GS+ S) and grass silage plus 6 kg concentrate dry matter (DM) cow/d and milked twice daily (EXTLAC). Subsequent to the OWP (84 days) cows were turned out to pasture (SFP). Results are outlined in Experiment II.

Design of Decision support system

The decision support system (DSS) was used to simulate a farm model, integrating biological data for each finishing system (FS). The model integrates purchase price, sale price, feed, housing, land and labour costs. Land area and housing was treated as an opportunity cost. Variable costs (fertilizer, veterinarian fees, silage and concentrate) and fixed costs (labour, machinery maintenance and running costs, farm maintenance, car, telephone, electricity, and insurance) were based on current prices (Teagasc, 2008). The values for meat and milk price were obtained from projections from the Food and Agricultural Policy Research Institute-Ireland Outlook 2008 (Binfield, Donnellan, Hanrahan, & Westhoff, 2008).

Risk Analysis

Stochastic simulation was included in the DSS model using the computer software @Risk (Palisade, 2006), which executes a Monte Carlo risk assessment (also called Monte Carlo uncertainty assessment). This process specifies a probability distribution for each sensitivity parameter, draws a set of those parameters, and repeats the conventional analysis for multiple draws. A sufficiently large number of simulations were run (10,000) with the same input distributions, so that the probability distribution functions of the outputs were adequately described.

Stochastic budgeting was used to model the influence of variation in cull cow purchase price, carcase selling price, milk price and concentrate cost. The milk price and concentrate cost input distributions were developed using 10 years of historical data (CSO, 2008). The computer program Bestfit was used to create empirical probability distributions for cull cow price. For cow selling price, data for the months of December, March, April and May for 2000 to 2008, from a number of meat factories in Ireland were included. These were included in the model for each finishing strategy based on the days to slaughter for each of the finishing strategies. The Bestfit program selected the Normal distribution for December carcase value, Beta general distribution for March sell value, Logistic distribution for April and May sell values. For both milk price and concentrate costs, the Extreme value distribution was selected as the optimum. All distributions were selected using the Chi Square test statistic and were visually assessed to ensure the visual appearance was correct. The feeds offered (grass, grass silage, straw and concentrate) were determined by the Moorepark Dairy Systems Model (MDSM) (Shalloo et al., 2004), milk production, live weight change (Jarrige, 1989), and body condition score (BCS) change (Lowman, et al. 1976). The key default parameters used in the model farm are shown in Table 6.1.

The four stochastic variables were concurrently simulated with no correlation assumed between variables. The output variable was selected as annual net profit per cow for each of the finishing strategies. Outputs of the analysis are shown in the form of cumulative distribution functions (CDF). The stochastically dominant set was found by comparing the CDF of risky prospects. A CDF contains all of the information on the output distribution of the risky prospects and therefore provides a useful decision-making criterion by assessing stochastic dominance.

Results

Feed budget

The total DM intake for each strategy was 1.4, 1.5, 1.4, 1.4, 1.9, 2.0 and 2.5 tonnes/cow for the GS, GS+3, GS+6, GS+9, GS+G, GS+S and EXTLAC treatments, respectively. Total UFL intake was 1264, 1232, 1247, 1244, 1455, 1984 and 2400 UFL/ cow in finishing feed for the GS, GS+3, GS+6, GS+9, GS+G, GS+S and EXTLAC treatments, respectively.

Cull cow price

In Table 6.2 cull cow beef price shows substantial seasonal trends and year to year variation. The seasonal trend in cull cow carcase value shows higher prices offered during the spring and early summer months, reaching a peak in May and June and subsequently dropping to a minimum in the November and December months.

Economic implications of strategies evaluated

Table 6.3 shows the key output parameters from the model for the eight strategies investigated which include seven FS and a control group slaughtered at lactation end. All cows on the seven FS were finished to TARGET carcass criteria. The highest profit was realised with the EXTLAC strategy (€235/cow). The total costs of production were marginally different between the GS, GS+3, GS+6, GS+9, GS+G and GS+S feed strategies. The lowest profit was achieved by the GS+9, utilizing 9 kg DM of concentrate daily resulting in a profit figure of €131 per cow. The EXTLAC strategy produced 1263 kg milk which resulted in milk sales receipts of €513/cow. Feed and labour costs for the EXTLAC strategy were, respectively, 30% and 80% greater than the average costs associated with the same period (OWP) for the other 6 dietary strategies. The production of milk (milk sales) during this period, however, resulted in the EXTLAC strategy returning the highest profit (milk sales output was greater than the increased additional cost in feed). Feed costs per kg of carcass were lowest for the GS+G and GS+S strategies; these systems achieved the highest margin per kg of carcass with the exception of the EXTLAC strategy.

Risk Analysis

Fig. 6.1 shows the plotted CDF of variation in net profit per cow resulting from variation in milk price, concentrate cost, purchase price and sale price for seven finishing strategies. The graph shows that there was little difference in the distributions of farm profit for the GS, GS+3, GS+6, GS+9, GS+G and GS+S finishing strategies. The mean farm profit with the GS, GS+3, GS+6, GS+9, GS+G, GS+S and EXTLAC was €85.3, €73.7, €95.6, €58.5, €158.8 and €186.8 and €283.0 respectively; with 90% confidence intervals (5% to 95%) of -€234.6 to €406.7, -€245.5 to €385.5, -€221.9 to €416.2, -€298.7 to €349.9, -€153.5 to €472.9, -€133.2 to €499.7 and -€35.0 to €602.3, respectively (Table 6.4).

The EXTLAC strategy shows a preferential first degree stochastic dominance to all the strategies evaluated. First degree stochastic dominance means that for any given level of risk there is a greater level of profit or conversely for a given level of profit there is reduced risk when the CDF is further to the right. For the other FS combinations (GS, GS+3, GS+6, GS+9, GS+G and GS+S), there was some crossing over of the individual CDF lines on the cumulative probability distribution graph. Therefore the principle of second degree stochastic dominance must apply, which takes into account the utility function of the farmer where the farmer's level of aversion to risk will affect the preferred strategy.

Age

The highest profit (€159.7), final carcase weight (330 kg) and final carcase value (€831.4) was realised with the 3-6 lactation category. The lowest profit (€89), and carcase weight gain (0.55 kg/day) was achieved with the >7 lactation category, which corresponded to the highest total costs. The highest ADG was achieved with the <2 lactations (0.98 kg/day). However, due to their initial live weight being substantially lower at the start of the finishing period compared to the 3-6 and >7 lactation categories, the final carcase weight achieved was lower than the other two age categories and it took longer to reach the TARGET weight.

Discussion

The proposed utility of this model is to help with the decision making process of farmers in relation to cull cow finishing specifically 1) if cull cow finishing is viable 2) the most economically viable finishing strategy under varying farm resources and management alternatives. A function of any beef production strategy is the variability of key input and output variables. The DSS developed in this study captures the effect of this variability through stochastic budgeting and highlights the large influence of finishing strategy employed on enterprise profitability within Irish cull cow beef production strategies.

DSS Models

Within the world of agriculture a great amount of research resources have been devoted to the development of DSS to enhance the decision making capabilities of primary producers and their advisers. These initiatives have been driven by the increased complexity of agricultural production brought on by market globalization, the need for sustainable production practices, and the increasing rate and volume of information exchange. Decision support tools can assist producers in making more informed decisions by integrating information from a number of sources which may recommend altering production strategies, enhancing management skills, and reducing costs of production. The DSS described in the present study in the context of beef production can make decisions for producers whether to finish cull cows or not. It can also help the producer with cost reduction, improved productivity and sustainability by matching livestock requirements to feed inputs. Within Ireland there is a seasonal nature to cull cow price and there is a seasonal nature to finishing strategies due to the grass based milk production systems employed. This adds to the complexity of the decision making process and required incorporation into the DSS developed. The complexity of decisions in relation to strategy options ensure the requirement for a dynamic DSS based on simulation techniques to represent different variables and the main interactions between these variables of the strategies.

This DSS is designed to be used by extension officers in conjunction with their farmer clients to identify the key strategies for cull cow finishing. Through extension officers using the tool it is expected that some of the more progressive computer literate farmers will also adopt the technology and use the tool.

Influence of strategy selection on farm profit

Feed costs in a cull cow enterprise account for more than half of the overall costs (Hughes, 1995) (when there was no costs included for animal purchase), hence associated costs with different feed types (concentrate, grass silage and grass) and its availability (weather and geological location) are principal factors to consider when selecting the optimum dietary strategy to best suit individual farm resources. Biological increases in output are often associated with increased input costs and where adequate nutrients are supplied in the basal diet, supplementary concentrate feeding can influence overall farm profitability only through its influence on animal production performance (McCarthy, Horan, Dillon, O'Connor, Rath, & Shalloo, 2007). The EXTLAC strategy resulted in greater feed input costs (concentrate and labour) in comparison with the other 6 strategies, however increased sales surpassed costs associated with increased feed and labour, making it the most profitable strategy evaluated. While the EXTLAC strategy was the most profitable strategy evaluated, its success is reliant on four factors; (i) the availability of a milking facility on the farm site, (ii) the prevailing milk price, (iii) milk quota availability and (iv) labour availability.

The increased output associated with production of milk in the EXTLAC system will not be possible on non-dairy farms. Therefore the optimum strategy on these farms for cull cow finishing will focus on minimising costs. Numerous studies carried out in Ireland (Dillon, Crosse, Stakelum, & Flynn, 1995; Shalloo et al., 2004) have shown that grazed grass is the cheapest feed available. The two strategies (GS+G and GS+S) evaluated in this study which finished cull cows from grazed grass returned a substantially higher profit than any of the other finishing strategies where milk production was not carried out.

Risk Analysis

The stochastically efficient or dominant set is found by comparing the CDFs of risky prospects. Fig. 6.1 shows the CDF for the spread in strategy net profit resulting from variation in milk price, purchase and selling price and concentrate costs. Including variability in the models provides greater information for the decision maker with key decisions. Risk analysis indicated that profitability for the EXTLAC strategy was stochastically dominant to all other strategies, meaning there is a higher level of profit and a lower level of risk associated with the EXTLAC strategy. The model described in the present study helps the decision maker with routine regulatory decisions by accounting for variation in milk price, cull cow sale value, cull cow purchase value and concentrate costs on net profit per cow. In the scenarios evaluated the EXTLAC strategy shows stochastic dominance to all other strategies evaluated.

Conclusion

The DSS shows the optimal cull cow beef production strategy depends greatly on the prevailing economic environment; purchase and sale price, milk price, feed costs, housing and labour. The results indicate that the most profitable strategy was the EXTLAC strategy, which achieved €283 net profit per cow. For non-dairy farmers the highest profit was achieved with cull cows fed a proportion of their finishing diet from grazed grass. Risk analysis suggests that the EXTLAC strategy shows stochastic dominance over all other options. Live-weight and age are key components of the profitability of cull cow finishing strategies in Ireland. A DSS tool is now available for extension officers in Ireland which will allow analysis of cull cow finishing strategies.

Table 6.1. Assumptions used in the model finishing strategy

Item	Default Value
Concentrate (€/t)	280
Grass silage (€/t)	130
Straw (€/t)	94
Grass (€/t)	70
Labour, feeding (€/hr)	0.01
Labour, milking (€/hr)	0.06
Opportunity cost of housing (€/wk)	1.4
Opportunity cost of land (€/ha)	267
Milk Price (€/kg)	0.42
Med, Vet and other (€/cow)	20

Table 6.2. Mean value (c/kg) offered for TARGET carcass in Irish commercial slaughter facilities from 2000 to 2008.

Month €/kg	n	2002	2003	2004	2005	2006	2007	2008
January	182.4	158.9	134.8	163.0	200.9	221.3	220.5	236.9
February	193.3	152.2	146.5	181.6	215.7	229.7	224.0	267.7
March	196.6	145.2	148.6	185.5	221.4	235.4	226.5	263.4
April	201.9	151.2	150.6	198.2	222.3	242.3	228.9	270.4
May	201.8	153.1	156.0	208.6	221.2	244.2	220.5	272.1
June	197.2	149.1	156.8	213.8	206.1	228.8	221.5	281.1
July	188.2	136.4	146.3	203.3	181.7	210.3	206.6	262.5
August	183.1	131.5	147.8	169.9	186.2	215.0	210.5	262.2
September	186.4	130.9	143.3	174.4	186.6	218.5	212.0	265.8
October	179.5	125.6	144.0	169.0	160.2	219.3	208.0	262.9
November	180.9	112.1	144.8	171.6	155.9	217.5	211.5	254.9
December	177.2	113.6	150.1	159.6	202.5	207.6	224.3	-
Year	189.0	138.3	147.5	183.2	196.7	224.2	217.9	264.5

Source: Department of Agriculture and Food (2008).

n, 10 year average of total cow numbers slaughtered per month in Ireland.

Table 6.3. Key herd parameters in a quota scenario using up to date costs and prices for 8 finishing strategies for cull dairy cows, assuming a purchase price of 1.26 c/kg and selling price of 2.52 c/kg

	Indoor strategies				Outdoor strategies		
Parameter (€ / cow)	GS	GS+3	GS+6	GS+9	GS+G	GS+S	EXTLAC
Labour feeding	1.22	1.08	0.95	0.84	1.15	1.48	1.57
Labour milking	-	-	-	-	-	-	4.62
Milk sales	-	-	-	-	-	-	513
Livestock sales	811	815	821	809	811	829	804
Feed costs	185	251	275	297	209	196	337
Total costs	597	649	663	678	654	631	934
Margin per cow	214	166	158	131	157	198	235
Feed costs/kg carcass	2.87	3.59	3.74	4.35	3.06	2.68	5.76
Margin/kg of carcass	3.32	2.37	2.15	1.92	2.30	2.70	4.02
Total profit	214	166	158	131	157	198	235

Table 6.4. The mean, 5% and 95% confidence intervals for each of the finishing strategies based on the stochastic distributions.

Finishing strategy	Mean	(CI 5%), €	(CI 95%), €
GS	85.3	-234.6	406.7
GS+3	73.7	-245.5	385.5
GS+6	95.6	-221.9	416.2
GS+9	58.5	-298.7	349.9
C	0	-165.5	163.6
GS+G	158.8	-153.5	472.9
GS+S	186.8	-133.2	499.7
EXTLAC	283.0	-35.0	602.3

GS, grass silage; GS+3, grass silage and 3 kg concentrate/day; GS+6, grass silage and 6 kg concentrate/day; GS+9, grass silage and 9 kg concentrate/day; C, slaughtered on D 0; GS+G, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 k g concentrate/day.

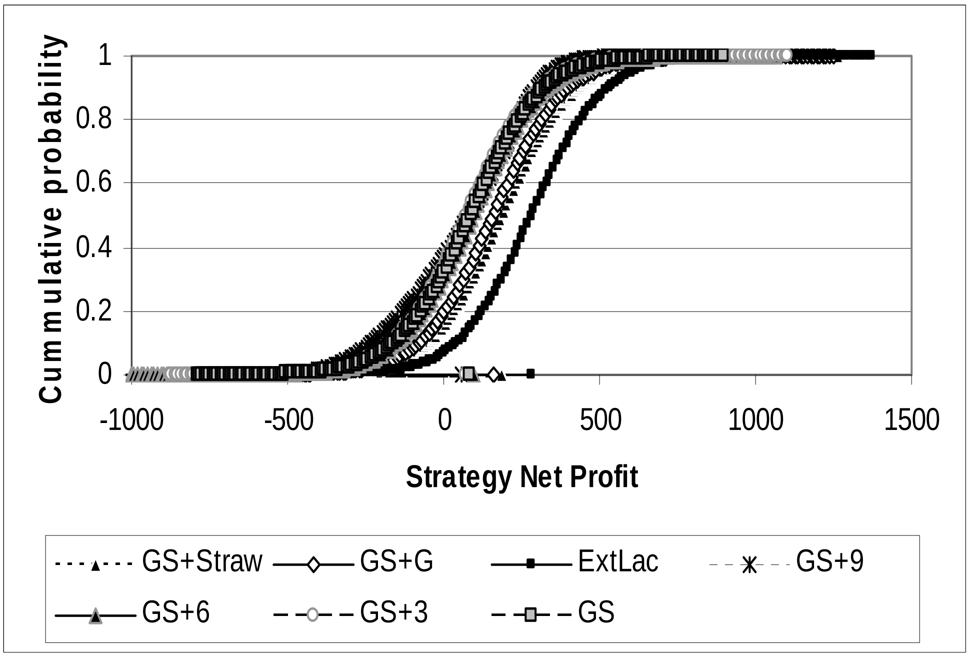

Fig. 6.1. Cumulative probability distribution showing the influence of milk price, cull cow sale value, cull cow purchase value and concentrate costs on net profit per cow. GS, grass silage; GS+3, grass silage and 3 kg concentrate/d GS+6, grass silage and 6 kg concentrate/day; GS+9, grass silage and 9 kg concentrate/day; C, slaughtered on Day 0; GS+G, grass silage; GS+S, grass silage and straw 0.30; EXTLAC, milking group offered grass silage and 6 k g concentrate/day.

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6. Publications

A1 Minchin, W., Buckley, F., Kenny, D.A., Monahan, F.J., Shalloo, L., & O'Donovan, M.A. (2009). Effect of Grass Silage and Concentrate Based Finishing Strategies on Cull Dairy Cow Performance, Carcass and Meat Quality Characteristics. *Meat Science*, 81: 97-102.

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