

ECONOMIC ASPECTS OF PRODUCING CASTRATES, MALE PIGS AND IMMUNOCASTRATES

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Main conclusion

Production costs per kg carcass for male pigs and immunocastrates are DKK 0.61 (0.08 €) and DKK 0.11 (0.014 €) lower compared with castrates. In the current economic climate, this balances rejection rates of 14% for male pigs and of 2% for immunocastrates to reach break-even compared with castrates.

Abstract

This report, which is the final part of a comprehensive investigation comparing production of castrates, male pigs and immunocastrates, analyses the economy of producing castrates, male pigs and immunocastrates, respectively.

Previous reports include: "Productivity and boar taint in castrates, male pigs and immunocastrates" [3] and "Castrates, male pigs and immunocastrates – behaviour & penile injuries" [4].

The cost of producing 1 kg carcass is DKK 0.61 (0.08 €) and DKK 0.11 (0.014 €) lower for male pigs and immunocastrates, respectively, compared with castrates. The analyses in this trial report exclusively concern differences in production costs as all other factors relating to the price of a male pig/immunocastrate are a function of supply/demand and rejection limits for boar taint (March 2021).

The main differences concern feed conversion ratio (FCR) and lean meat content. In the period from 30 kg live weight to slaughter (89 kg carcass weight), pig producers save 28.6 and 17.7 feed units¹/pig, respectively, in production of male pigs and immunocastrates compared with castrates. With a feed price of DKK 1.57 (0.21 €) per feed unit there is an overall saving in feed costs per pig of DKK 45.0 (6.00 €) and 27.8 (3.71 €) for male pigs and immunocastrates, respectively, compared with castrates. Lean meat content was 3.4 and 2.5 percentage points higher for male pigs and immunocastrates, respectively, compared with castrates, which alone results in a higher payment per pig for male pigs and immunocastrates of DKK 32.9 (4.39 €) and 25.8 (3.44 €), respectively, compared with castrates.

Compared with male pigs, the price of immunocastrates must cover the additional cost of DKK 25.5 (3.40 €) per pig for Improvac vaccines and vaccination. Pig producers save approx. DKK 8 (1.07 €) per pig in pain relief, labour related to castration and a lower mortality in the weaner period by omitting castration.

Boar taint – primarily for androstenone, but to some degree also for skatole - can be reduced by using AI boars with a high or low degree of androstenone. Future rejection limits for boar taint have yet to be decided nationally and internationally, but are likely to include androstenone. Today, rejection in Denmark is only based on skatole, and using this as the basis, there are economic advantages in producing male pigs compared with castrates and immunocastrates.

The cost of producing an immunocastrate is approx. DKK 0.50 (0.07 €) higher per kg and lean meat payment is DKK 0.08 (0.01 €) lower per kg compared with male pigs. However, skatole and androstenone levels in meat from immunocastrates are lower compared with male pigs, which means that the risk of boar taint and rejection is significantly lower. These calculations show that with the current prices and conditions, the expected overall benefit of immunocastration is equal to production of castrates.

Background

Production of male pigs includes a range of advantages compared with production of castrates:

1. No surgical castration (elimination of tasks related to castration, administration of pain relief and local anaesthesia, and lower mortality rates among male piglets).
2. Feed conversion ratio and lean meat content are better in male pigs compared with castrates.
3. Improved utilization of nutrients in the feed = lower carbon footprint.

Production of male pigs is generating increasing interest in several European countries for animal welfare reasons. However, several of the Denmark's main export markets still hesitate to buy pork from male pigs due to the risk of receiving meat with boar taint. Figures show that in 2020 male pigs accounted for **3.6% of all** pigs slaughtered in Denmark [5].

Immunocastration is a way to reduce boar taint: male pigs are vaccinated with an anti-gonadotropin-releasing-hormone (GnRH) at approx. 30 kg and again 4-6 weeks before slaughter. Vaccination inhibits the production of male hormones, ie. the pigs' traits become like castrates before slaughter. The advantage is that the positive production traits known from male pig production, such as higher gain, a better FCR and a higher lean meat content, are maintained until shortly before slaughter [1], [2], [3], which generates a lower production cost. The question then is whether the rejection rate of immunocastrates combined with the production cost are enough to pay for the vaccine. Previous

¹ *) one feed unit i.e. 12,8 MJ metabolizable energy and 7,7 MJ physiological energy

Danish studies found a better FCR and lean meat content among male pigs compared with castrates [1] and that immunocastrates grow faster than castrates [2].

Material and method

The aim of this part of the study is to make a cost-benefit analysis producing castrates, male pigs and immunocastrates. For a detailed description of materials and methods, see trial report no. 1219, 'Productivity and boar taint in castrates, male pigs and immunocastrates' [3].

The trial comprised six groups: castrates, male pigs and immunocastrates sired by either high-androstenone or low-androstenone AI boars (see trial design in table 1).

Table 1. Trial design

Androstenone AI boars	High	Low
Castrates	120	120
Male pigs	120	120
Immunocastrates	120	120

To be able to make a cost-benefit calculation, production results were standardized to a start weight of 30 kg and a carcass weight of 89 kg. A dressing percentage of 1.31 was used for conversion of carcass weight to liveweight for all three genders. The standardization equations used are the ones used in Danish efficiency reports, ie. a Gompertz growth function with peak daily gain at approx. 85 kg live weight [6]. There is a marginal feed consumption gradient mean slope of 0.0169 [5] in the national average when the reference consumption in a given weight interval is standardized based on female pigs/castrates. Feed consumption in a given weight interval is:

$$FE_{sv} \text{ kg gain } (V_{si} - V_{su}) = FE_{sv} \text{ kg gain } (V_i - V_u) + 0.5 * (V_{si} + V_{su} - V_i - V_u) * K$$

V_{si} and V_{su} represent the desired standardization weight interval, V_i and V_u and FE_{sv} /kg gain represent values recorded on the farm, and K is the marginal feed consumption slope constant.

Prices and assumptions

Average five-year prices (September 1, 2015-September 1, 2020) based on the average weaner price were used as the basis of the calculations.

- Finisher feed (five years): DKK 1.57 (0.21 €) per feed unit
- Settlement slaughterhouse per kg carcass before adjusting for lean meat % and male pig deduction: DKK 11.12 (1.48 €) per kg
- Weaner price: DKK 394 (52.53 €) per 30 kg pig
- Wages: DKK 180 (24.00 €) per hour
- Seven additional days in production included to adjust for weighing out pigs
- Assumption: 3.5% dead and rejected for all three groups. The trial is not designed to identify differences in mortality between the three genders.
- Rent per pig place: DKK 0.71 (0.095 €) a day covering depreciation, interest and maintenance.

Price correction for male pigs and immunocastrates

A pig producer wishing produce male pigs must have a contract with the slaughterhouse and this type of production is subject to a deduction from the regular pig price of DKK 0.31 (0.041 €) per kg (March 2021) to cover sampling, analyses and sorting of male pigs. This calculation assumes an identical deduction on immunocastrates. Analyses of boar taint and sorting routines are expected to apply to immunocastrates also in the near future. When a male pig is rejected at slaughter, an additional deduction from the price is imposed, which is regulated on a quarterly basis depending on the

composition of this type of meat. In the second quarter of 2021, this deduction amounted to DKK 4.60 (0.61 €) per kg, and this is the value applied for the sensitivity calculations in the results section of this report.

Rejection of male pigs and immunocastrates depends on skatole and androstenone thresholds. Today, slaughterhouses apply rejection limits for skatole only (0.25 ppm) and do not apply a defined rejection limit for androstenone. Consequently, calculations in this report are aimed at identifying the maximum rejection rate to maintain break-even - as a minimum - in the production of male pigs and immunocastrates as an alternative to castrates.

Lean meat content price is calculated according to the below function which takes into account variations in lean meat content.

$$DKK/kg \text{ in lean meat \% adjustment: } = \frac{(-0.8149 * (\text{Lean meat \%} * 100; 2) + 111.58 * \text{Lean meat \%} * 100 - 3776.9)}{100}$$

$$€/kg \text{ in lean meat \% adjustment: } = \frac{(-0.1094 * (\text{Lean meat \%} * 100; 2) + 14.98 * \text{Lean meat \%} * 100 - 507)}{100}$$

This does not include reduction in the carcass value due to variation in carcass quality i.e. meat and fat quality, different in meat distribution of different parts between the three genders, or potential market loss as a consequence of male pig production [7].

Productivity figures

The productivity figures recorded in the trial form the basis of the economic calculations (table 2) [3].

Table 2. Daily gain, feed intake and feed conversion, carcass weight and lean meat %. Age and weight at intermediate weighing [3].

		Castrates	Male pigs	Immuno-castrates	SEM	
Pigs		235	203	203	0.5	0.42
Daily gain, g	Period 1	1,132 ^a	1,104 ^{ab}	1,090 ^b	0.01	0.03
	Period 2	1,229 ^a	1,301 ^b	1,252 ^a	0.01	<0.01
	Entire period	1,196 ^{ab}	1,212 ^a	1,180 ^b	0.01	<0.01
Feed conversion, FUp/kg	Period 1	2.31 ^a	2.11 ^b	2.15 ^b	0.02	<0.01
	Period 2	3.19 ^a	2.70 ^b	3.01 ^c	0.02	<0.01
	Entire period	2.76 ^a	2.41 ^b	2.61 ^c	0.01	<0.01
Feed intake, FUp/day	Period 1	2.58 ^a	3.32 ^b	2.32 ^b	0.03	<0.01
	Period 2	3.90 ^a	3.48 ^b	3.73 ^c	0.03	<0.01
	Entire period	3.30 ^a	2.92 ^b	3.07 ^c	0.02	<0.01
Lean meat %		60.1 ^a	63.5 ^b	62.6 ^c	0.2	<0.01
Carcass weight, kg		89.6	89.2	88.9	0.4	Ns
Dressing percentage		1.33 ^a	1.36 ^b	1.36 ^b	0.01	<0.01
Weight at transfer, kg		38.5	37.2	37.4		
Weight at intermediate weighing, kg		74.3	72.3	70.7		
Feeding days Period 1		32.7	32.4	34.0		

a, b, c values with different superscripts within a row are significantly different $p < 0.05$

Period 1: transfer to before 2nd vaccination.

Period 2: before 2nd vaccination to slaughter.

Entire period: from transfer to slaughter.

The actual dressing percentage is higher for male pigs and immunocastrates than for castrates due to the removal of testicles from the carcass.

Savings (DKK (€)/male pig) by omitting castration

Pig producers overall save DKK 8.14 (1.09 €) per pig by omitting castration in the production of male pigs or immunocastrates.

Pig producers save costs for local anaesthesia, pain relief and labour related to castration and equipment (scapels and needles) which are estimated to amount to DKK 6.14 (0.82 €) per pig.

Furthermore, analyses reveal a slightly lower pre-weaning mortality among uncastrated pigs, corresponding to DKK 2 (0.27 €) per male pig (see table 3).

Table 3. Savings, DKK (€)/male pig and immunocastrate

Action	DKK (€)/piglet
Pain relief	0.72 (0.096 €)
Local anaesthesia	2.93 (0.39 €)
Labour	2.50 (0.33 €)
Lower mortality pre- and post-weaning	2.00 (0.267 €)
Weaner price, saved by omitting castration, total per male pig/immunocastrate	8.14 (1.09 €)

Improvac[®] injection

An Improvac vaccination costs DKK 24 (3.2 €) for two doses per pig (Zoetis, March 2021), incl. injector and needle. Labour (including time for preparation and vaccination) amounts to DKK 1.5 (0.20 €) per finisher, corresponding to ½ minute per pig for two vaccinations.

Results and discussion

Productivity figures and the differences between male pigs, immunocastrates and castrates is based on standardized calculations (table 4). The standardized figures show a small improvement (marginal) for castrates. This is attributed to the fact that towards the end of the growth period castrate efficiency is lower than among male pigs and immunocastrates and more identical in the first part of the growth period.

Table 4. Standardized daily gain and feed conversion ratio (FCR) in the period 30 kg live weight to 89 kg carcass weight (116.6 kg live weight) in castrates, male pigs and immunocastrates.

	Castrates	Male pigs	Immuno-castrates	Male pigs-castrates	Immuno-Castrates	Male pigs-Immuno
Daily gain, g, 30 kg to 116.6 kg	1,166	1,176	1,151	14	-15	25
FUgp/kg gain, 30 kg to 116.6 kg	2.85	2.53	2.65	-0.33	-0.20	-0.12

Economy

Pig producers producing male pigs or immunocastrates save 28.67 (11.4%) and 17.7 (7.0%) FUgp/finisher in the period from 30 kg to slaughter compared with castrates. There is hardly any difference in the number of pigs produced per place unit/year and the current pig price is therefore not as important to the cost-benefit calculation. The feed price, however, is important. The feed prices used in the calculations of DKK 1.57 (0.21 €) per feed unit is an average of five years and is the expected longterm feed price in Denmark.

Table 5. Economic assumptions and impact analyses.

Assumptions	Castrates	Male pigs	Immunocastrates
Start weight, kg	30	30	30
Price/pig weaned, DKK (€)	394 (52.53 €)	394 (52.53 €)	394 (52.53 €)
Weaned pigs, not castrated, saved in DKK (€)	0.0 (0.0 €)	8.1 (1.08 €)	8.1 (1.08 €)
Lean meat %	60.1	63.5	62.6
Carcass weight, kg	89	89	89
Live weight, dressing percentage 1.31, kg (* carcass weight)	116.59	116.59	116.59
FUgp/kg	2.85	2.53	2.65
Dead and rejected, %	3.5	3.5	3.5
Total feed consumption per pig produced, kg	251.4	222.7	233.7
Price/FUgp, DKK (€)	1.57 (0.21 €)	1.57 (0.21 €)	1.57 (0.21 €)
Daily gain, g	1,166	1,176	1,151
Days per pig from start to slaughter	83.9	82.9	84.9
Pigs slaughtered per place unit/year	4.35	4.39	4.30

Payment due to lean meat content is DKK 32.9 (4.39 €) and 25.8 (3.44 €) higher per pig for male pigs and immunocastrates than for castrates. However, this must be seen in the light of a male pig deduction of DKK 27.59 (3.68 €) per pig in 2021. The value of male pigs is also lower due to changes in meat and fat quality and differences in distribution of meat in the various carcass parts between the three genders [7], and finally potential market loss from male pig production. These values are not included in the calculations.

Table 6. Carcass price, per pig, before deductions.

	Castrates	Male pigs	Immunocastrates
Male pigs, boar taint analysis, deduction, DKK (€)/pig	0.0 (0.0 €)	27.59 (3.68 €)	27.59 (3.68 €)
Rejected male pigs, deduction DKK (€)/kg	0.0 (0.0 €)	4.6 (0.61 €)	4.6 (0.61 €)
Pig price corrections, DKK (€)			
Pig price, DKK (€)/kg	11.12 (1.48 €)	11.12 (1.48 €)	11.12 (1.48 €)
Male pig deduction, DKK (€)/kg carcass weight	0.00 (0.0 €)	-0.31 (-0.041 €)	-0.31 (-0.041 €)
Lean meat % payment, correction per kg, DKK (€)	-0.14 (-0.0187 €)	0.23 (0.031 €)	0.15 (0.02 €)
Pig price per kg, DKK (€)	10.98 (1.46 €)	11.04 (1.47 €)	10.96 (1.46 €)

The pig price before rejection due to boar taint is nearly identical for all three genders (table 6). The higher lean meat payment for male pigs and immunocastrates fully or partly covers the male pig deduction of 0.31 DKK (0.041 €) per kg.

Before rejection due to boar taint, results show an excess gross margin for male pigs and immunocastrates of DKK 59.15 (7.89 €) and 8.20 (1.09 €) per pig, respectively, compared with castrates. Calculations of economic equilibrium for male pigs and immunocastrates show that this can

cover up to 14.5% rejected male pigs and 2% rejected immunocastrates assuming a deduction of DKK 4.6 (0.61 €) per kg (April 2021).

Table 7. Gross margin, DKK (€) /pig sold or per place unit/year.

Gross margin (GM) estimate	Castrates	Male pigs	Immuno-castrates
GM/pig			
Income/pig if not rejected at slaughter, DKK (€)	976.9 (130.3 €)	982.2 (130.96 €)	975.1 (130.01 €)
Purchase price, 30 kg pigs, reduced if no castration, DKK (€)	408.3 (54.44 €)	399.9 (53.32 €)	399.9 (53.32 €)
Improvac vaccine, 2 vaccinations DKK (€)	0.0 (0.0 €)	0.0 (0.0 €)	24.0 (3.2 €)
Labour, 2 Improvac vaccinations DKK (€)			1.5 (0.2 €)
Feed costs DKK (€)	394.7 (52.63 €)	349.8 (46.64 €)	367.0 (48.93 €)
Rent DKK (€)	59.7 (7.96 €)	59.2 (7.89 €)	60.4 (8.05 €)
GM, DKK (€)/pig	114.2 (15.23 €)	173.3 (23.11 €)	122.3 (16.31 €)
Difference castrates, DKK (€)/pig	-	59.1 (7.88 €)	8.2 (1.09 €)
Difference production costs per kg compared with castrates, DKK (€)	-	-0.61 (-0.081 €)	-0.11 (-0.015 €)
Rejected at same GM as castrates, %	-	14.44 (1.93 €)	1.64 (0.22 €)
GM, DKK/place unit	1,166 (155.47 €)	1,176 (156.8 €)	1,151 (153.47 €)
Income per place unit, DKK (€)	4,252 (566.93 €)	4,308 (574.4 €)	4,194 (559.2 €)
Weaners saving, DKK (€)	1,777 (236.93 €)	1,754 (233.87 €)	1,720 (229.33 €)
Improvac vaccination, incl. wages, DKK (€)	0.0 (0.0 €)	0.0 (0.0 €)	103 (13.73 €)
Feed costs, DKK (€)	1,718 (229.067 €)	1,534 (204.53 €)	1,578 (210.4 €)
GM/place unit, DKK (€)	757 (100.93 €)	1,020 (136 €)	793 (105.73 €)
Difference castrates, DKK (€)/place unit if 0% rejected	-	263 (35.067 €)	36 (4.8 €)

When are male pigs rejected due to boar taint?

The threshold for rejection of male pigs in 2021 is > 0.25 ppm skatole. In future, both skatole and androstenone will be included in the assessment of male pigs. Today, there are no established rejection limits for androstenone. International literature applies androstenone levels of 1 or 2 ppm as

the threshold for boar taint, but these thresholds are **not** the accepted quality criterium in a sales situation.

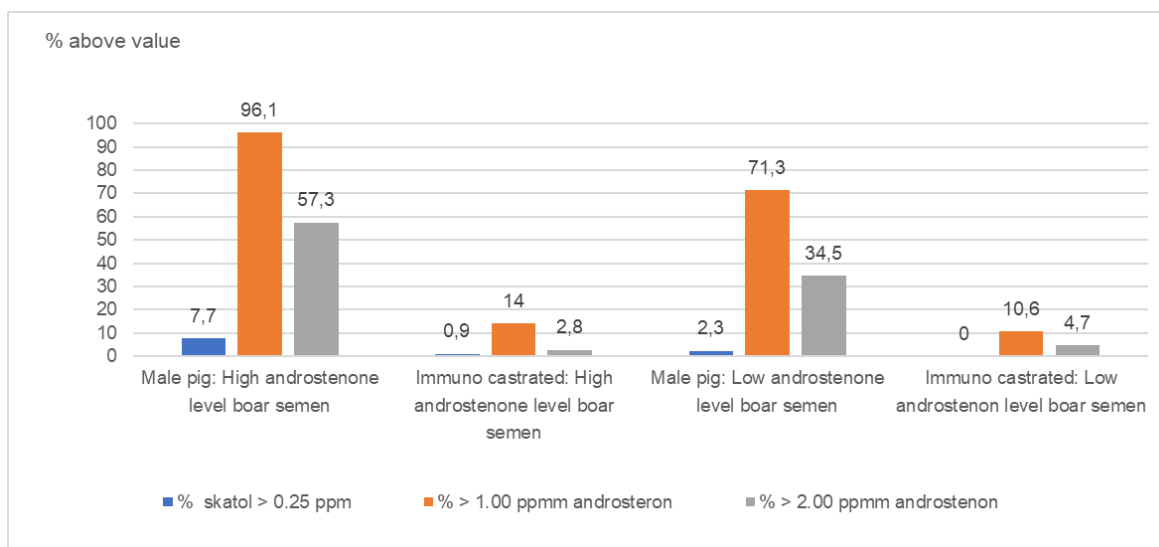


Figure 1. Rejection rates, male pigs, due to boar taint at different thresholds for boar taint. Source: Trial report no. 1210, SEGES Pig Research Centre.

With the current rejection limits based on skatole, production of male pigs is significantly more economical than production of immunocastrates and castrates (table 8).

Table 8. Economy under current Danish Crown rejection limits for boar taint and skatole values found in trials.

AI boars androstenone	High			Low		
	Male	Immuno	Male - Immuno	Male	Immuno	Male - Immuno
Male pig rejection under current skatole limit (%)	7.7	0.9	6.8	2.3	0	2.3
Marginal GM/pig compared with castrates, DKK (€)	27.6 (3.68 €)	3.7 (0.49 €)	23.9 (3.19 €)	49.7 (6.63 €)	8.2 (8.20 €)	41.5 (5.53 €)
Marginal GM/place unit compared with castrates, DKK (€)	125.0 (16.67 €)	16.5 (2.20 €)	108.5 (14.47 €)	221.9 (29.59 €)	35.8 (4.77 €)	186.2 (24.83 €)
Marginal GM/pig compared with AI boar with high/low androstenone, DKK (€)				22.1 (2.95 €)	4.5 (0.60 €)	17.6 (2.35 €)
Marginal GM/place unit compared with AI boar with high/low androstenone, DKK (€)				97.0 (12.93 €)	19.3 (2.57 €)	77.7 (10.36 €)

It is technically possible to sort AI boars according to high/low androstenone levels. This will improve the economy of male pig production as it will positively affect the percentage of male pigs found with boar taint, which in turn will lead to lower rejection rates and an overall better pig price, everything else being equal.

Sensitivity under different price correction (DKK (€)/kg) for rejected male pigs

The maximum percentage of rejected male pigs while allowing for economic balance compared with production of castrates depends on the deduction, which is determined by the market price. There is a small marginal economic advantage in producing immunocastrates compared with castrates. Consequently, there is very limited room for rejection of immunocastrates in order for gross margin to be the same as for production of castrates (table 9). Assuming a deduction for a rejected pig with boar taint of, for instance, DKK 4.6 (0.61 €) per kg, producers of male pigs can have up to 14.4% rejected, while producers of immunocastrates can only have up to 2% rejected.

Table 9. Sensitivity calculations, rejection rates for male pigs and immunocastrates at a given level of boar taint deduction.

DKK (€)/kg	Male pigs, %	Immunocastrates, %
3.6 (0.48 €)	18.5	2.6
4.1 (0.55€)	16.2	2.2
4.6 (0.61 €)	14.4	2.0
5.1 (0.68 €)	13.0	1.8
5.6 (0.75 €)	11.9	1.6

Production of male pigs in other countries

Table 10 shows data compiled in 2018 by the Thunen Institute in Germany concerning production of male pigs, including immunocastrates (compiled in one value) in a number of countries [8].

Table 10. Male pig production in 2018 in different countries responding to the survey [32]

	In % of national slaughterings	Approx. in % of male pigs, total	Male pig slaughterings/year	Year of data
Austria	0	0	0	2018
Belgium	8	16	508,080	2018
The Czech Republic	1	1	5,900	2017
Denmark	3	7	567,600	2018
France	10	20	2,371,280	2018
Germany	10	20	5,468,964	2017
Ireland	50	100	3,500,000	
Italy	0	0		
Holland	39	78	6,119,000	2018
Spain	40	80	19,830,101	2018
Sweden	0	1	1,170	2018
Switzerland	0	0		
UK	46	92	10,700,000	
Australia	43	86		

With the requirement of full anaesthesia during castration introduced in Germany in 2021, slaughterhouses such as Tummel will start considering immuncastration as an alternative.

In 2020 in Denmark approximately 7 % of all male piglets were slaughtered as male pigs. It is uncertain how importers of Danish meat will react if this number increases significantly as not all

export markets are prepared to buy products from male pigs. The positive economic aspects of male pig production in Denmark may therefore be in jeopardy if the production of male pigs increases, as this may in fact lead to a rise in both the deduction for male pigs/immunocastrates plus a deduction for rejected male pigs. One Danish slaughterhouse is currently installing new analysis equipment for analysis of both skatole as well as androstenone. Sorting male pigs on the basis of both skatole and androstenone values is likely to increase the current rejection rates, which may make immunocastration relevant if we wish to produce more uncastrated male pigs in Denmark.

Conclusion

The cost of producing 1 kg carcass is DKK 0.61 (0.8 €) and 0.11 (0.015 €) lower per kg for male pigs and immunocastrates, respectively, compared with castrates. In the period 30 kg live weight to 89 kg carcass weight, analyses reveal a saving per pig of 28.6 and 17.7 feed units in production of male pigs and immunocastrates, respectively, compared with castrates. With a finisher feed price of DKK 1.57 (0.21 €) per feed unit, feed costs per pig are DKK 45.0 (6.00 €) and 27.8 (0.37 €) lower for male pigs and immunocastrates, respectively, compared with castrates. In the production of immunocastrates, there is an additional cost to be covered of DKK 25.5 (3.40 €) per pig for Improvac vaccines and labour related to vaccination.

Male pigs and immunocastrates have a higher lean meat content which alone leads to DKK 32.9 (4.38 €) and 25.8 (3.44 €) higher per carcass compared with castrates.

If calculating the economic equilibrium for male pigs and immunocastrates compared with castrates, this can pay for rejection rates up to 14.5% for male pigs and 2% for immunocastrates if deduction amounts to DKK 4.6 (0.61 €) per kg (April 2021).

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