Economic Values for Meat Quality Traits

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Summary and Implications

A method was developed to calculate economic values for pork quality traits for use in genetic selection. The method considers the normal variability of pork quality traits within a herd or population. The parameters required for this method are the mean, standard deviation, and range of the quality trait within the herd or population, and the relationship of the level of the quality trait with price received for pork at the consumer level. The method was applied to results from a consumer preference study of quality traits of pork loin that was conducted by the National Pork Producers Council. Resulting economic values of percentage of lipid (lipid%), Instron score, and ultimate pH were $.9112, $-.4040, and $-.3469, respectively, per kilogram of loin per unit increase in the trait. Results indicate that efforts to increase lipid% and to decrease Instron score can result in extra revenues for swine production. The sign of the economic value for ultimate pH was opposite to expectations, which is a reflection of the results of this specific consumer preference study. A second preference study is currently under way and its result will be used to reevaluate economic values. Alternative methods to select for quality traits, such as optimum linear indexes and indexes based on a quadratic aggregate genotype, were discussed.

Introduction

Meat quality is an important aspect of swine production. Several consumer preference studies, including one conducted by the National Pork Producers Council (13), have provided the evidence that consumers can discriminate between levels of meat quality. Each segment of the pork quality chain contributes to the development of quality pork. Exploiting genetic variation by including meat quality traits in the breeding goal of a pig breeding program is one possibility to improve meat quality.

During the last quarter of 1994, the NPPC (13) conducted a national consumer taste preference study to determine the economic values of meat quality traits. This study involved the meat quality traits of ultimate pH, total lipid content, and Instron score, and was conducted among approximately 160 consumers each in Chicago, Atlanta, Boston, and San Diego. Based on the NPPC (13) consumer preference study, economic values of meat pork quality traits were derived and documented by Melton et al. (11). Economic values were derived by evaluating the extra price consumers are willing to pay for pork loin that is of a quality that is marginally better than average. Economic values thus derived are appropriate for use in genetic selection if all pigs are average or when the effect of quality on price is linear. Neither of these situations applies for derivation of economic values for pork quality traits. Therefore, derivation of economic values of pork quality traits must consider the variability or distribution of pork quality traits within a group of pigs that is marketed. Hovenier et al. (7) developed a method to derive economic values of quality traits that accounts for the distribution of the quality trait in the population. Based on this method, von Rohl et al. (14) estimated economic values for meat quality traits in pigs. This method, however, assumes presence of a categorical price function, in which price premiums are based on a classification of the carcass according to a pricing grid. The results from the NPPC (13) consumer study, however, provide a continuous rather than a categorical relationship between the quality trait and price.

Consumers are ultimate benefactors of improved quality of meat. The demand for quality meat will result in the inclusion of quality traits in the breeding goal and in selection decisions. This will require prediction of eating quality based on live animal or carcass measurements. Several studies have shown a positive relationship between lipid% and eating quality (1, 13). The NPPC study also showed that ultimate pH had a positive relationship with water-holding capacity. Goodwin et al. (5) concluded from previous NPPC research that ultimate pH, total lipid content, and Instron score were associated with pork loin tenderness and juiciness. Tenderness and juiciness are greatly preferred by consumers. Although pork quality is only one component of pork production, it may be an important driving factor for the future of industry. Proper analysis of the economic values of quality traits is important to determine proper emphasis on individual traits for genetic selection to improve pork quality

Objectives of this study were to develop a method to calculate economic values for pork quality traits that accounts for the variability of pork quality traits in a population and to apply this method to results from the national consumer preference study conducted in 1994 (13).

Materials and Methods

Derivation of the method. The economic value of a pork quality trait is defined as the increase in profit per pig if the average pork quality in a population is

improved by one unit. Thus, economic values are defined at the population level rather than at the level of an individual pig. The starting point for the derivation of the economic value of a pork quality trait is a profit function of the following form:

$$f(trait)=P(trait)–C(trait) \quad [1]$$

where f(trait), P(trait), and C(trait) are the profit, price, and cost functions associated with the quality trait. We first assume an individual profit function, which describes the relationship of the quality trait for an individual pig with profit. The individual profit function may be derived from consumers and production research based on the fact that consumers are willing to pay more for high quality meats and that producers may need to bear additional costs to produce pork of higher quality. The next step is to apply this individual profit function to the range or distribution quality trait levels that are represented in a population of pigs. This step is needed because the magnitude of the extra profit that can be obtained by improving quality differs for the range of quality values that are present among animals in a population if the relationship between the quality trait and profit is nonlinear. Therefore, an average profit function is defined as the relationship between population average for the quality trait and the average profit for animals in the population. Given the distribution of the quality trait in the population, g(trait), average profit of the population for a given population mean of the trait, μ, (AP(μ)) can be calculated by integrating the individual profit function f(trait) over the distribution of the trait in the population

$$AP(\mu)=\frac{\int_{LB}^{UB} f(trait)\,g(trait)\,f(trait)}{\int_{LB}^{UB} g(trait)\,f(trait)} \quad [2]$$

where UB and LB are the upper and lower bounds for the quality trait in the population, respectively. Here, distributions for each trait were assumed to be truncated normal distributions. According to the above definition, average profit levels can be calculated based on equations [1], [2] for a range of population means. Average profit levels will be depend on the population mean (μ), the standard deviation of quality traits (σ), the upper and lower bounds of the population range, and individual profit functions f(u). Therefore, a more general form of equation [2] is

$$AP(u) = f(u / \sigma, LB, UB, f(u)). \quad [3]$$

The relationship of the average profit function to the individual profit function and the distribution of the trait is illustrated in Figure 1.

According to the definition of economic values given by Hazel (6), economic values are the marginal profit change if the population mean is changed by selection. Therefore, The economic values of improving quality traits in the population can be found as the first derivative of equation [3] with regard to μ and evaluated at the given population mean.

Application. A national consumers preference study was conducted in 1994 in four cities. Melton et al. (11)

quantified the effect of increasing meat quality on retail prices based on a fixed pork purchase probability of .2794 relative to chicken. Results from this analysis [equation (16) of Melton et al. (11)] were used to develop the following individual price functions to simulate the effect of a quality trait on the retail price for pork loin per kilogram

$$f(lipid\%)=2.2026*e^{0.8929+0.3375\ln(lipid\%)} \quad [4]$$

$$f(Is)=2.2026*e^{1.7848-0.2877\ln(Is)} \quad [5]$$

$$f(pH)=2.2026*e^{20.5350-6.5303(pH)+0.5534(pH)^2} \quad [6]$$

where f(lipid%), f(Is), f(pH) are the individual prices for pork loin ($/kg) associated with lipid%, Instron score, and ultimate pH, respectively. Here, each quality trait was assumed to be truncated normally distributed. The parameters of the distribution were based on the results of the NGEP (13), as shown in Table 1. Based on equation [3], an average price function can be derived for each trait by integrating equations [4], [5], and [6] over the distribution of the trait for a range of population means.

The economic values of lipid%, Instron score, and ultimate pH are the first derivatives of equation [3] by substituting the appropriate f(trait) and g(trait). Also, the economic values presented in the NGEP were computed based on the method used by Melton et al. (11), which was the first derivative of individual price functions (Figure 1). The two economic values were compared. Integrals in all equations were solved numerically using Matlab 5.2 (9) for a range of population means.

Results and Discussion

Figures 2, 3, and 4 show the individual prices consumers are willing to pay per kg of pork loin as a function of lipid%, Instron score, and ultimate pH. Individual price functions were based on equations 4, 5, and 6, as obtained from the NPPC consumer preference study. Graphs show that the price that consumers were willing to pay increased with lipid% but in a nonlinear manner. An increase in Instron score had a negative impact on price. Ultimate pH had an effect on price that was opposite to expectations, with an increase in price for both low and high pH and the lowest price for intermediate levels of pH.

Figures 2, 3, and 4 also show the average price functions, which were derived using equation 1 based on the trait parameters. The average price functions show the relationship between the population mean for the trait and the average price received across animals in a population. In general, differences between the individual and average price functions were small.

Figures 5, 6, and 7 show the economic values for lipid%, Instron score, and ultimate pH. Two sets of economic values are shown, one based on the individual price function and one that is based on the average price function. Graphs show that the economic values depend on the population mean for the trait. The economic value

for lipid% decreased with lipid% (Figure 5). This means that genetic improvement in lipid% is less valuable if lipid% is already high. The economic value based on the average price function was slightly higher than the economic value based on the individual price function. For the current population mean for lipid% of 3.09, the economic value based on the average price was $0.91 per kilogram of loin per percent increase in lipid%. This value was slightly higher than the economic value based on the individual price function, which was $0.86 (13).

Figure 6 presents the two sets of economic values for Instron score. The economic value based on the average price function was lower than the economic value based on the individual price function when the population mean was greater than 4.5. For the current population mean Instron score of 5.9, the economic value based on the average price was $-0.40 per kilogram of loin per one unit increase in Instron score, which was lower than the economic value based on the individual price function, which was equal to $-0.38 (13).

Figure 7 shows that the economic value of pH increased with ultimate pH. The economic value was negative for pH less than 6. The economic value based on the average price function was generally higher than the economic value based on the individual price function for pH. For the current population mean pH of 5.8, the economic value based on the average price function was $-0.35 per kilogram of loin per unit increase in pH. This was slightly higher than the economic value based on the individual price function, which was equal to $-0.56 (13).

Table 2 summarizes the economic values for quality traits based on the average price model at the current population mean. The economic values also are shown on a basis of one genetic standard deviation relative to other traits. The genetic standard deviations of quality traits were based on the results of the National Genetic Evaluation Program (NGEP) (13).

Based on the proposed method, this study has quantified economic values of quality traits while taking into account the distribution and inherent variability in pork quality traits within a population of pigs. Although differences between economic values derived based on the average versus individual price functions were not large, the results indicated that the individual price model would slightly underestimate or overestimate prices for quality traits (Figures2, 3, and 4). Therefore, it would be useful to adopt the average price model instead of the individual price model when deriving economic values of quality traits. Differences between the two methods of deriving economic values will be greater if the individual price function exhibits a greater degree of nonlinearity, for example when prices are established based on a pricing grid. This situation was considered by Hovenier et al. (7). For the current population of 5.8, the economic values of ultimate pH based on the individual and average price functions derived here were $-5.31 and $3.32 per slaughter pig. Hovenier et al. (7) gave the economic value of $-51.48/per slaughter pig at the ultimate pH of 5.8 assuming the population mean of 5.65 in the Netherlands.

von Rohr et al. (14) found the weighted mean of economic value of $0 at the pH of 5.5 in Switzerland

Exploiting genetic variation by including meat quality traits in the breeding goal of a pig breeding program is one possibility to improve meat quality (3, 10). Optimal utilization of genetic evaluations for quality traits, in combination with genetic evaluation for other traits, involves determining economic values for improving quality traits relative to the economic importance of improving other traits (2). A method to derive economic values for meat quality traits based on a consumer preference study was developed and applied in this study. Although the economic value of improved productions traits (e.g., growth rate) is independent of population mean, the economic value of quality traits does depend on the population mean (Figures 5, 6, and 7). For the current population, the economic values of increasing lipid% and decreasing Instron score for pork loin by one genetic standard deviation were $5.88 and $3.82/per slaughter pig, respectively (Table 2). National Swine Improvement Federation estimated the economic value of $1.59/per day slaughter pig for the days to 113.39 kg by one genetic standard deviation. The value of ultimate pH indicated that consumers preferred a relatively low and high ultimate pH pork (Figure 4), which was opposite to expectations. The reason might be that breed of sire difference were confounding the ultimate pH classes. The Hampshire-sired pigs have low ultimate pH and tender loins, where the Berkshire-sired pigs have high ultimate pH loins. This difference in ultimate pH is thought to be due to the RN gene in pigs (8). From this standpoint, these economic values may be biased due to confounding factors. Further consumer study is needed.

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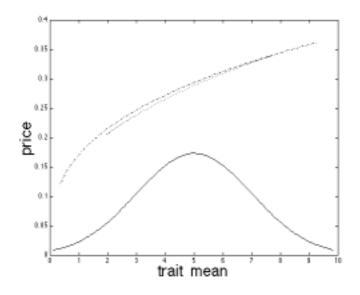
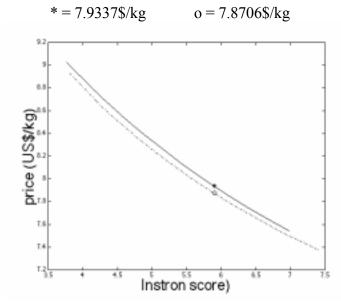**Figure 1. Individual (-.) and average price functions (.) with based on a truncated normal distribution (-).**

* = 7.9337$/kg   o = 7.8706$/kg

Figure 3. Individual price (-.) and average price functions (-) for Instron score.

* = 7.655$/kg   o = 7.875$/kg

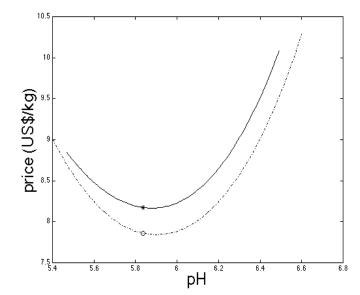**Figure 2. Individual price (-.) and average price functions (-) for lipid%.**

* = 8.1740$/kg   o = 7.8615$/kg

Figure 4. Individual price (-.) and average price functions (-) for ultimate pH.
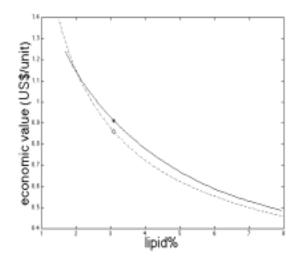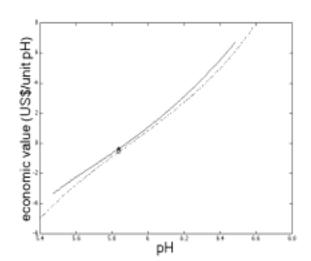
* = .9117   o = .8590

* = -.3469   O= -.5557

Figure 5. Functions of economic values based on individual price (-.) and average price function (-) for lipid%.

Figure 7. Economic values based on individual price (-.) and average price functions (-) for ultimate pH as function of population mean.

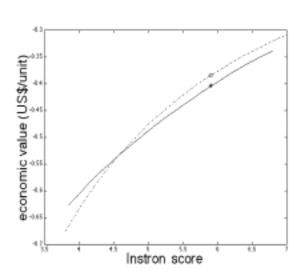* = -.4040   o = -.3839

Figure 6. Functions of economic values based on individual price (-.) and average price functions (-) for Instron.

Table 1. Parameters of normal distribution for quality traits.

Quality trait	Population mean	Standard deviation	Lower Bound	Upper Bound
Lipid%	3.09	1.19	.36	9.26
Instron score	5.90	1.63	2.70	10.00
Ultimate pH	5.84	.27	5.25	7.16

Table 2. Economic values of quality traits for current population mean.

Quality trait	Economic value ($/kg loin/unit increase in trait)	Economic value * genetic standard deviation ($/per slaughter pig)
Lipid%	.91	5.88
Instron score	-.40	-.3.82
Ultimate pH	-.35	-.3.32