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EFFECTS OF THE NAKED GENE ON POSTWEANING PERFORMANCE AND THERMOTOLERANCE CHARACTERS IN FRYER RABBITS

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ABSTRACT

This investigation quantified the effects of the naked gene on postweaning and thermotolerance characters in rabbit fryers during 42-d growth trials in summer of 2002 in subtropical south Texas. In 1999, a rare naked rabbit was mated to commercial New Zealand White does, resulting in 16 F_1 litters and 113 offspring, all of which had normal fur coats. To expose the recessive naked gene in the homozygous state, F_1 X F_1 *inter se* matings were made between half-siblings to create an F_2 generation. Based on the expected 3:1 phenotypic ratio (furred to naked), in the F_2 generation, 192 rabbits had normal fur coats and 48 rabbits were naked, supporting the single recessive gene hypothesis (χ^2 = 2.94; P>0.05). Weaned fryers were randomly assigned to growing pens containing either two or three furred or naked non-littermates. Individual fryer traits included initial and final body weights and ADG, as well as respiratory rate and rectal body temperature. Pen traits included feed and water intake. For individual traits, data were blocked for random effects of fraternal-litter and pen (nested within treatment), and fixed effects of treatment (naked and furred groups), age batch, gender, fixed effect interactions, and initial age of fryer (linear covariate). Results revealed (P<0.001) that naked compared to furred fryers had heavier final weights (1996 versus 1784 g) and more rapid ADG (27.3 versus 24.0 g/d). Pens of naked compared to furred fryers, on average, had higher feed intake by 28 g/d per fryer (P<0.001), but pen feed efficiency (total gain/total feed intake) was poorer for naked than for furred rabbits (0.230 and 0.279; P<0.001). Daily water intake was similar (199 and 188 ml), on average, between pens of naked and furred fryers. However, furred compared to naked fryers had a higher free water-to-feed intake ratio (2.13 and 1.72 ml/g; P<0.01). At 1400 hr, naked fryers had lower rectal temperatures (38.9 and 39.7 ºC) and lower respiratory rates (120 and 161 breaths per minute) compared to furred rabbits, respectively. Our results suggest that naked rabbits had better heat tolerance and(or) a higher critical body temperature zone than furred rabbits, and hence better growth performance. This preliminary experiment yielded promising results in favor of naked rabbits, but additional trials are needed to confirm these results.

Key words: fur, growth, rabbits, thermoregulation, tropical agriculture.

INTRODUCTION

Poverty and malnutrition is of great concern, especially in the lesser developed countries located in arid and tropical regions of the world (WHO, 2001). Rabbit meat is an ideal food source in this region due to the low cost of production and ability to integrate rabbits into most small-farm production systems (MCNITT *et al.,* 2000). However, rabbits reared in tropical climates are prone to heat stress. Perspiration is not an effective method of heat control due to the rabbit's fur. Rather, rabbits use three methods to modify heat loss: general body position, breathing rate, and peripheral temperature (LEBAS *et al.,* 1997). In temperate environments, furred rabbits normally gain 40 grams a day, but in arid and tropical environments, daily weight gains typically drop to 20 grams, although temperature alone is not the sole cause for the decline in growth (LUKEFAHR and CHEEKE, 1991). Furred rabbits also require special care to prevent heat-related deaths, sometimes preventing poor farmers from producing or consuming rabbit meat as regularly as is potentially possible.

The rare event of furless or naked rabbits was first reported in Russia by KISLOVSKY (1928), then from Hammond's population in Britain by CASTLE (1933), and then much later in France by BOUCHER *et al.* (1996). The furless gene prevents the formation of fine wool hairs (underfur), leaving primarily the long and coarse guard hairs. In contrast, the naked gene differs from the furless mutation in that the rabbit can be entirely devoid of any fur or hair. The furless and naked genes have been reported in many species, such as in cats, mice, hamsters, guinea pigs, micro-pigs, dogs, and non-human primates (BOUCHER *et al.*, 1996). Theoretically, furless or naked rabbits should direct more energy towards growth rather than to fur production, and have better thermoregulation ability when exposed to periods of extreme heat and humidity. However, the effect of the naked gene has not been previously investigated to determine its potential benefits on rabbit production. Altered trait expressions, such as furless coats, could potentially yield new breeds that are better capable of adapting to hot, arid and(or) humid environments, especially in lesser developing countries where rabbit development programs exist to benefit limited-resource families.

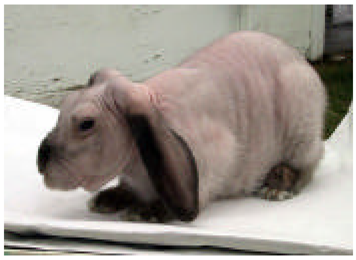
The research goal of this breeding project was to evaluate the naked gene and its effects on production of rabbit fryers under extreme temperature and humidity stress conditions in south Texas. More specifically, our objectives were to: 1) determine the mode of inheritance of the naked gene; 2) quantify the effects of the naked gene on production traits involving growth, feed and water intake, and survival; and 3) examine the effects of the naked gene on morphological and physiological expressions, such as ear length and type, body temperature, and respiration rate.

MATERIALS AND METHODS

Population management

The study was initiated in January of 2001 by the donation for breeding of a rare naked Mini-Lop buck born in El Campo, Texas. "Fuzz" (photo), was mated to commercial New

Zealand White (NZW) does, resulting in 16 litters and the birth of 113 F_1 kits. In turn, F_1 half-siblings (13 bucks and 19 does) were mated *inter se* to produce F_2 progeny to expose the presumed single recessive, naked gene. For this purpose, fall 2001 and spring 2002 matings were conducted. Rabbits from large (>10 kits) and small (≤3 kits) litters were crossfostered into fraternal groups. Kits were scored for coat type (normal or naked) at 1 wk of age.



Animal management and trait measurements

The study was initiated with four age batches of weanlings in July and August of 2002. Representative of a tropical environment, ranges of mean temperatures and relative humidity levels recorded inside the building were 33.2 to 35.1 ºC and 61.5 to 64.6% RH, respectively. All kits were weaned, weighed and tattooed at 28 d of age, and moved as a litter group to a temporary pen. When at least three litters had been weaned, kits were randomly assigned to growing pens on the same day as an age batch, but limiting each pen to only one kit per fraternal litter. In large litters, a limit of six furred kits was sampled for the study. Growing cages contained two or three naked or furred fryers. Rabbits were fed an *ad libitum* supply of a commercial diet. Pen feed intake was monitored daily, following a 1-wk adjustment period to the growing pens. Water was supplied continuously using 900 ml water bottles to record water intake. During the 6-wk growth-phase trials, outside ambient and inside hutch temperatures were recorded daily at 1400 hr. At the end of each trial, all naked rabbits in each pen, but only one furred rabbit per pen (randomly chosen), had rectal temperature (taken using a clinical thermometer inserted 6 cm) and respiratory rate (recorded as the number of flank movements per 20 sec, later calculated as breaths/min) measurements taken (THWAITES *et al*., 1990). All rabbits were weighed weekly to monitor growth. Mortality was recorded throughout the experiment.

Statistical procedures

To analyze individual fryer growth data, the experimental design was a split-plot with whole plots consisting of treatment (furred and naked classes), sub-plots consisting of pens of fryers (23 furred and 8 naked pens), and residual error consisting of within-pen variation. The pen source served as the error line for testing the treatment effect. Data were blocked for the additional random effect of fraternal litter, and for fixed effects of age batch (four groups), gender, fixed interactions, and initial age as a linear covariate (mean of 42.2 d, range of 28 to 49 d), corresponding to the age when a fryer was placed on the study. Data were subjected to ANOVA procedures employing LSMLMW software (HARVEY, 1990). In preliminary analyses of growth traits, 1st and 2nd order interactions were never important (P>0.05), and so were eliminated from the model. For temperature and respiration rate data, the same model was used, except that the random pen effect was eliminated. To test the hypothesis that the naked gene was inherited as a simple autosomal recessive, the expected 3:1 phenotypic ratio of furred-to-naked offspring hypothesis was tested by χ^2 using F_2 observed data. For pen data (feed and water intake per rabbit), ANOVA procedures were used with treatment and age batch as model main effects.

RESULTS AND DISCUSSION

Mode of inheritance

The fall 2001 matings produced 91 F_2 rabbits (70 and 21 furred and naked), and the spring 2002 matings produced 149 F_2 rabbits (122 and 27 furred and naked), which were scored at 1 wk of age, yielding combined observed frequencies of 80.0 and 20.0%, confirming the hypothesis (χ^2 = 2.94; P>0.05) that the mode of inheritance is due to a single recessive gene, which is in agreement with the earlier report by CASTLE (1933). Interestingly, considerable F_2 genetic segregation for coat and skin color, ear length and position (*e.g.,* erect or lopped), body size, *etc*., was observed. From spring 2002 matings, of the 22 naked rabbits surviving to weaning age, it was further observed that naked rabbits exhibited three distinct versions: Class 1 (18.2%), "buzzy" (left photo), little to no fur on the body, head, neck, and feet; Class 2 (36.4%), "fuzzy" (middle photo), a light and short coat of fur over the entire body; and Class 3 (45.5%), "wuzzy" (right photo), a light and longer coat of fur over the entire body. However, in all three classes, the fur appeared to be less dense than that of a normal furred rabbit. These observations are in agreement with CASTLE (1933) who reported that the degree of "nakedness" can vary among rabbits, presumably due to modifier genes.

From the spring 2002 cohort, 92 rabbits were subjected to growth-phase trials (70 furred and 21 naked rabbits). One weanling fryer died at the onset of the study (a naked animal that may have been traumatized from a blood collection). KISLOVSKY (1928) reported that all naked rabbits from one litter in his study died by 1 mo of age. CASTLE (1933) observed that the furless gene did not appear to be lethal prior to birth, although he assessed that furless rabbits were difficult to keep alive and had low fertility. BOUCHER *et al.* (1996) described seemingly different versions of the furless or naked gene that appeared in three commercial herds in France. However, in their report, only one specimen that closely resembled our Class 1 rabbits later died at 80 d of age. The other specimens more closely resembled our Class 3 rabbits, which they described as "hairless". Autopsies of their hairless rabbits revealed several internal maladies, including stomach ulcers, pyloric stricture, and cecal paralysis. In our population, we surmise that a unique furless mutation possibly exists that does not seem to adversely affect performance or vitality. However, it has been observed that naked kits may be more predisposed to early eye infections, but ointment treatment applications were successful in preventing permanent eye injury or blindness. While not reported herein, subsequent breeding trials also have revealed that naked rabbits are quite fertile and are capable of rearing young. Fur from normal does was transferred to complete the fur-straw nest, although artificial materials (*e.g.,* cotton and wool) could be used.

Fryer growth performance

From the spring 2002 cohort, there were 92 F_2 offspring (70 furred and 22 naked) from 18 litters available for the growth-phase study, which was conducted during the two hottest months of the year (July and August) in order to challenge all rabbits to a hot and humid environment to determine possible favorable trait associations with the naked gene. Previously, MEDELLIN and LUKEFAHR (2001) reported that in summer-weaned litters only 15% of fryers weighed at least 1.8 kg by 70 d of age, compared to 88.1, 61.9, and 88.6% in winter, spring, and fall. These results paralleled a dramatic depression in total litter feed intake (28 to 70-d) of 16.5 kg of litters weaned in summer due to the hot and humid climate, compared to 30.1, 25.0, and 27.1 kg for litters weaned in winter, spring, and fall, respectively. In the present study, naked fryers tended (P=0.0571) to be heavier initially by 58 g than furred fryers (least-squares means of 838$\pm$33 and 780$\pm$26 g). However, final weights were significantly heavier by 212 g in favor of naked compared to furred rabbits (1996$\pm$47 and 1784$\pm$30 g; P<0.001). Likewise, body weights were consistently heavier for all weeks in favor of naked rabbits (Figure 1).

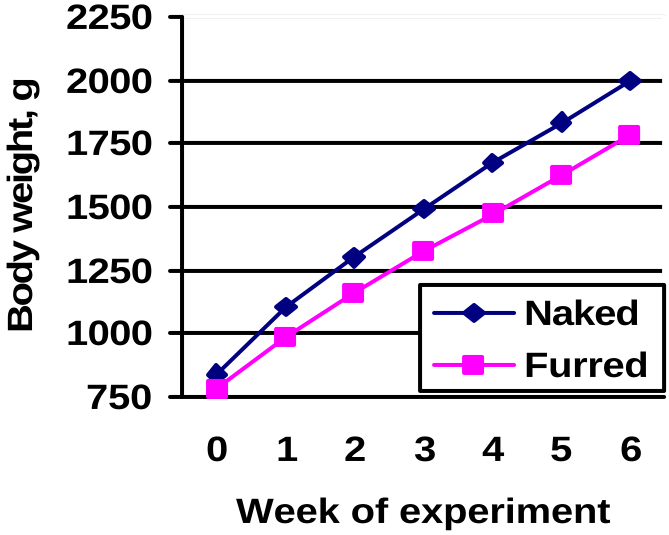


Figure 1. Body weight plots for naked and furred rabbits.

In addition, naked rabbits had more rapid ADG than their furred counterparts, 27.3±0.76 and 24.0±0.55 g/d ($P<0.001$). Because naked rabbits tended to be heavier initially than furred rabbits, a supplemental analysis was performed to adjust ADG for initial body weight (added as a linear covariate to the model). However, similar results were obtained. In a previous experiment conducted during the summer months, RUIZ-FERIA and LUKEFAHR (1998) reported on the effect of electrical fur clipping of fryer rabbits, which significantly increased ADG by 1.7 g/d and final body weights (approximately 70 d of age) by 73 g compared to furred (non-clipped) controls. These results associated the fur clipping effect with better feed intake (difference of 112 g/d), presumably due higher temperature/humidity suppression (lower critical temperature zone) of feed intake in non-clipped rabbits.

Feed and water utilization

Daily feed intake was greater by 28.9 g in naked than in furred rabbits (least- squares means of 114 and 86 g/d, respectively; $P<0.001$). This result reinforced our hypothesis that naked rabbits would consume more feed due to less heat-humidity stress (i.e., higher critical temperature zone). However, the greater feed intake may have contributed to a higher heat increment, associated with the high fiber diet (38.2 and 20.3% NDF and ADF) and hot climate interaction, because naked rabbits had poorer feed conversion rates (0.230 and 0.279 [total pen gain/total feed intake]; $P<0.001$).

Paradoxically, water intake per fryer in pens was not statistically different (199 and 188 ml/d; Table 1); however, naked rabbits were significantly heavier as previously stated. In reference to the general positive association between feed and water intake, EBERHART (1980) cited in LEBAS *et al*. (1997) reported that from 18 to 30 ºC, fryers consumed less feed (158 and 123 g/d) and had slower growth (37.4 and 25.4 g/d), while water intake rose from 271 to 386 g/d, respectively.

Table 1. Feed and water utilization in naked and furred rabbits[a].

	FI	FE	H_2O	H_2O/FI
Naked	114±4.2	0.230±0.012	199±10	1.72±0.10
Furred	86±2.7	0.279±0.008	188± 6	2.13±0.10
Sign.	$P<0.001$	$P<0.001$	$P=0.304$	$P<0.01$

[a] Trait abbreviations: FI=daily feed intake per fryer, g/d; FE=total pen gains/total pen feed intake; H_2O=daily water intake per fryer, ml/d; H_2O/FI=free water-to-feed intake ratio per fryer.

On average, pens of naked compared to furred fryers had a lower free water-to-feed intake ratio of 1.72 and 2.13 ml/g ($P<0.01$). Similar to the value of 2.13, JIN *et al.* (1990) reported a free water-to-feed intake ratio of 2.30 for NZW fryers reared in an environmentally controlled room at 30 ºC. However, as discussed below, it is plausible that furred fryers needed less free water to digest the lower quantity of ingested feed, but required proportionately more water to dissipate their higher body temperature. To support this explanation, in the largest batch 1 (18 out of 23 total pens), simple correlation coefficients between feed and water intake per fryer were 0.68 and 0.02 for pens of naked and furred rabbits. While the 0.68 correlation involving naked rabbits is reasonable, the erratic 0.02 correlation from furred rabbits may indicate their state of impaired thermal homeostasis. In future trials, it would be more useful to monitor water intake hourly rather than on a daily basis.

Conversely, in a colder climate, BOUCHER *et al.* (1996) also reported that hairless or naked rabbits appeared to have poor feed conversion due to excessive energy or radiation loss associated with thermoregulation, since fur is known to help insulate body temperature. However, this is not an issue in arid and tropical environments where it seldom freezes. Indicative of diverse comfort or thermoneutral zones, at 1400 hr, the behavior of naked rabbits appeared normal (mobile and alert), whereas furred rabbits were typically in a laying, stretched position and panting to dissipate body heat.

Associations of ear length and type

In a separate analysis, initial ear length and body weight were added to the model as linear covariates to determine associations with growth. Results revealed (P<0.001) that for every 1 cm increase in initial ear length, ADG and final weight increased by 2.2 g/d and 199 g, respectively. However, the slopes of the regression lines were parallel (P>0.05) between naked and furred rabbits. LUKEFAHR and RUIZ-FERIA (2003) reported varied associations between ear length and ADG in fur clipped compared to non-clipped rabbits (2.72 *versus* 1.33 g/d for every 1 cm increase in ear length). In addition, unadjusted for initial body weight, least-squares means for final ear length were similar (P>0.05) between naked and furred rabbits (10.4$\pm$0.16 and 10.5$\pm$0.09 cm).

In a supplemental analysis, ear type class (0, 1 or 2 = none, one or 2 ears erect) was scored at the end of the 6-wk trials for each age batch, and included as a fixed effect in growth trait models. The rationale for this analysis was based on the hypothesis that rabbits with erect ears should be better able to lower their body temperature under a prevailing breeze situation than rabbits with non-erect ears. Results revealed that rabbits with lopped-ears (both ears non-erect) had more rapid body gains (P<0.05) and tended (P=0.0781) to have heavier final weights (least-squares means of 1,965 g [n = 17 rabbits]) than rabbits with one (1,844 g [n = 49 rabbits]) or both ears erect (1,906 g [n = 25 rabbits]), regardless of the absence or presence of body fur. No interaction was detected (P>0.05) between fur class (naked and furred) and ear type class. However, in commercial herds, rapidly growing fryers are observed to temporarily have lopped ears, so it is not possible to surmise whether this finding is attributable to better heat tolerance or thermoregulation *per se* or is simply an artifact of faster growing rabbits.

Physiological response

Naked rabbits had lower core body temperatures at 1400 hr than furred rabbits (least-squares means of 38.9±0.05 and 39.7±0.03 ºC; P<0.001). BOUCHER *et al.* (1996) reported that naked rabbits had lower body temperatures than furred rabbits (37 and 39 ºC), although ambient temperature or time of year information was not provided. FINZI et al. (1986) found no relationship between ear width and body temperature in NZW rabbits subjected to 30 ºC in climatic chambers for 100 min; however, there was no mention of air circulation in the chambers, which is critical for ear function in thermoregulation. In the present study, respiratory rates were lower in naked than in furred rabbits (120±4.1 and 161±2.3 bpm; P<0.001). FINZI et al. (1992) reported that sheared compared to non-sheared NZW bucks took 180 and 220 bpm when placed for 5 hr in climatic chambers at 30 ºC and 75% RH. The more normal temperatures and respiratory rates exhibited by naked rabbits indicated a functional thermoregulation system (i.e., higher critical temperature zone), whereas furred rabbits had impaired thermal homeostasis.

CONCLUSIONS

These preliminary and promising results in favor of naked rabbits need to be confirmed through additional studies. If confirmed, future plans would appear justified to develop a new breed of naked rabbits, better adapted for arid and tropical regions, contributing more meat and income for limited-resource families.

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