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OPTIMUM WOOL HARVEST INTERVAL OF ANGORA RABBITS UNDER ORGANISED FARM CONDITIONS IN EAST CHINA

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Abstract: The present study was conducted to evaluate the commercial lifespan and optimum wool harvest interval of Angora rabbits. One hundred shorn Angora rabbits were housed in an organised farm to describe the wool production curve. It showed that the optimum wool harvest interval was 75 d, when fibre length reached 55.0 mm. Wool production was lower from the 3rd to the 6th mo (young stage) than from 7th to 28th mo and rapidly decreased from 28th to 31st mo and was the lowest from 31st to 33rd mo of age. Feed intake-to-wool production ratio was higher from 3rd to 4th and from 7th to 9th mo of age than during the adult stage, and increased from 31st to 33rd mo of age. Daily weight gain was significantly higher from 3rd to 4th mo of age than in any other periods of the adult stage, and was negative from 23rd to 33rd mo of age. Therefore, the study reveals that the commercial lifespan of Angora rabbits was approximately 28 mo. Furthermore, wool production was higher in spring and winter than in autumn, and was the lowest in summer. Concomitantly, feed intake-to-wool production ratio was lower in spring than in autumn and winter, and was the highest in summer. Finally, daily weight gain was higher in spring and autumn than in winter, and was the lowest in summer. This indicates that wool production was depending on the season, and decreased significantly in summer. Moreover, the spring provided the best conditions for Angora rabbits.

Key Words: Angora rabbits, age, daily weight gain, season, wool harvest interval, wool production.

INTRODUCTION

Angora rabbits represent valuable resources for the wool industry. Angora wool, which belongs to the luxury animal fibre category, is one of the most highly produced animal-hair fibres, after sheep wool and mohair. In 2000, the global Angora wool production was approximately 8000 metric tons (Schlink & Liu, 2003). China, which exports 92% of global rabbit wool, is the largest exporter of Angora wool. Angora wool production, which is the most important economic trait in Angora rabbits, is affected by genetic and non-genetic factors (Thebault *et al.,* 1992; Allain *et al.,* 1999; Katoch *et al.,* 1999; Rafat *et al.,* 2007).

Besides genetic (Wang *et al.,* 2014) and nutritional factors (Meale *et al.,* 2013), season also affects both wool yield and quality in sheep (Liu *et al.,* 2014). In fat-tailed Sanjabi sheep, feed intake, body growth, fibre follicle activity and wool growth vary with seasons (Salehian *et al.,* 2015). Similarly, wool production in Angora rabbits is seasonally affected (Rochambeau *et al.,* 2010). Climatic changes are a major threat to the viability and sustainability of Angora wool production systems in several regions of the world, including China (Gaughan *et al.,* 2010).

However, in commercial farming, Angora wool is harvested at regular intervals. Based on the season and harvesting method, there are variations in Angora wool fibre (Allain *et al.,* 2010). As per Chinese standards (Rong *et al.,* 2009), high quality Angora fibre is >45 mm in length (*in vivo* length >55 mm). Suitable wool harvest intervals and reasonable farm management practices may improve the quality and yield of Angora wool. The aim of this study was to evaluate

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the commercial lifespan, optimum wool harvest interval, wool production, feed intake and weight gain of Angora rabbits during different seasons in East China.

MATERIALS AND METHODS

Animals, feeding and sampling

At the beginning of the study, 100 shorn Angora rabbits (2 mo of age, 50% female) were housed individually in wire net cages of well-ventilated sheds in a rabbit breeding farm in Shandong Academy of Agricultural Sciences. Rabbits were fed a pelletised diet consisting of 14.38% crude fibre, 16.92% crude protein, 2.42% crude fat, 0.85% lysine, 0.21% cysteine and 1.06% calcium and 0.55% phosphorus, with a total digestible energy of 9.91 MJ/kg (Table 1). Rabbits were fed *ad libitum* and drank freely all the time.

Feed consumption was recorded per cage daily. Shed temperature and relative humidity were recorded twice daily at 8:00 h and 14:00 h. Fibre length at different body points (back, buttocks, neck and 2 sides of the body) were measured with a steel ruler. When Angora fibre was ≥55.0 mm in length, the wool was harvested with clippers and weighed individually. Shorn rabbits were weighed individually at each harvest date. This study was performed for approximately 3 yr, which represents the lifespan of Angora rabbits. Wool harvest date was also recorded for whole study period.

The whole procedure for experimental animals was performed in strict accordance with the guidelines (IACC20060101, 1 Jan, 2006) of the Institutional Animal Care and Use Committee of Institute of Animal Science and Veterinary Medicine, Shandong Academy of Agricultural Sciences. All protocols in IACC20060101 were in accordance with the international, national and/or institutional guidelines for care and use of animals.

Parameters studied

The days between 2 adjacent shearing dates were designated wool harvest interval. Each wool harvest interval was calculated. Harvest period refers to the period between 2 harvests and was recorded in numerical order from the beginning to the end (Table 2). Wool production, feed intake, weight gain, temperature and relative humidity of each wool harvest period were determined on day 0 and on the day prior to harvest.

Statistical analysis

Wool production, feed intake, feed intake-to-wool production ratio and daily weight gain in different wool harvest period were analysed by one-way ANOVA and Duncan's test using SPSS Statistics 17.0. Data are presented as mean±standard error of mean. A *P*-value <0.05 was considered statistically significant.

Table 1: Composition and nutrient levels of the experimental diet.

Ingredients	Percentage(%)	Nutrient levels[2]	Content
Corn	21.00	Digestible Energy (MJ/kg)	9.91
Soybean meal	22.00	Crude Protein (%)	16.92
Wheat bran	15.85	Crude fat (%)	2.42
Peanut vine	38.00	Crude fibre (%)	14.38
Calcium hydrogen phosphate	1.20	Calcium (%)	1.06
Salt	0.50	Phosphorus (%)	0.55
Lysine	0.20	Lysine (%)	0.85
Methionine (Met)	0.25	Met (%)	0.43
Premix[1]	1.00	Cystine (%)	0.21

[1]The premix supplied the following kg^{-1} of diet: Vitamins A 6000 IU; Vitamins D 900 IU; Cu: 5 mg; Fe: 50 mg; Mn: 10 mg; Zn: 50 mg.
[2]Values are calculated according to table of ingredients.

RESULTS

Wool harvest interval

At 2 mo of age, rabbits were shorn with clippers (1st period). During a 3-yr lifespan, Angora rabbits had 14 wool harvest periods. The wool harvest intervals are presented in Table 2. The wool harvest interval was approximately 65 d between the 2nd and 3rd periods, and 75 d between the 4th and 11th periods. However, between the 12th and 13th periods, when the rabbits were 26 mo of age, the interval increased to 80 d. Therefore, age stages had effects on fibre growth.

Wool production performance

Wool production is presented in Figure 1. Wool production was significantly lower in the 2nd and 3rd periods than during the 4th to 12th periods ($P<0.05$). Thereafter, wool production rapidly decreased from the 13th period, reaching the lowest during the 14th period ($P<0.05$). Therefore, the useful commercial life of Angora rabbits was approximately 28 mo (12th periods).

During the peak stage of wool production, there were significant differences among the seasons. Wool production was significantly higher in spring (7th and 12th periods) and winter (5th, 6th, 10th, and 11th periods) than in summer (8th and 13th periods) and autumn (9th period, $P<0.05$). The lowest wool production was in summer ($P<0.05$).

Feed intake-to-wool production ratio (Figure 2) was higher in the 2nd and 4th periods (youth stage) than during the adult animal stage. Additionally, feed intake-to-wool production ratio was the highest during the 14th period ($P<0.05$). Similar results were obtained with wool production. Feed intake-to-wool production ratio was lower in spring (7th and 12th periods) and winter (5th and 11th periods) than in summer (8th and 13th periods, $P<0.05$).

Daily weight gain (Figure 3) was higher during the 2nd, 3rd, and 4th periods (young stage), as the animals were in the growth phase. Thereafter, body weight changed gradually during the adult animal stage. However, from the 11th and 14th period, daily weight gain was negative ($P<0.05$). Therefore, animal age had a significant effect on daily weight gain. The daily weight gain significantly increased in spring and autumn (7th and 9th periods) compared to winter (6th, 10th, and 11th periods) and summer (8th and 13th periods, $P<0.05$). Therefore, the season has an effect on body weight in the adult rabbit.

Table 2: Wool harvest intervals of Angora rabbits during different harvest periods.

Wool harvest period[1]	Wool harvest date (yy.mm.dd)	Age (months)	Average temperature (°C)	Average relative humidity	Wool harvest intervals (days)[2]
2	12.04.06-12.06.11	3-4	23.3	53%	66
3	12.06.11-12.08.12	5-6	28.9	76%	62
4	12.08.12-12.10.25	7-9	22.4	74%	74
5	12.10.25-13.01.09	9-12	5.8	73%	76
6	13.01.09-13.03.25	12-14	5.3	80%	75
7	13.03.25-13.06.08	14-17	21.4	58%	75
8	13.06.08-13.08.28	17-19	29.7	75%	74
9	13.08.28-13.11.08	19-21	21.3	62%	72
10	13.11.08-14.01.23	21-23	7.2	76%	77
11	14.01.23-14.04.08	23-26	7.0	70%	76
12	14.04.08-14.06.26	26-28	25.4	54%	80
13	14.06.26-14.09.13	28-31	29.7	65%	79
14	14.09.13-14.12.01	31-33	18.9	68%	80

[1]Wool harvest period: the period between 2 harvests and was recorded in numerical order from the beginning to the end, represent as order number.
[2]Wool harvest interval: the days between 2 adjacent shearing dates, represent as days.

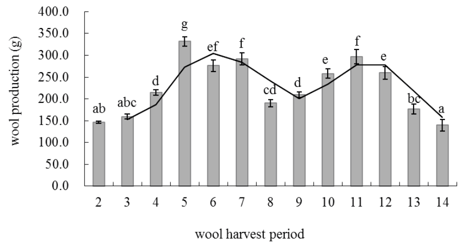

Figure 1: Wool production during different wool harvest periods. Wool production was lower during the 2nd and 3rd periods than during the 4th to 12th periods (P<0.05). Wool production was higher during the 5th, 6th, 7th, 10th, 11th and 12th periods than during the 8th, 9th and 13th periods, and the 14th period had the lowest value (P<0.05). Values with different superscripts differ significantly at P<0.05.

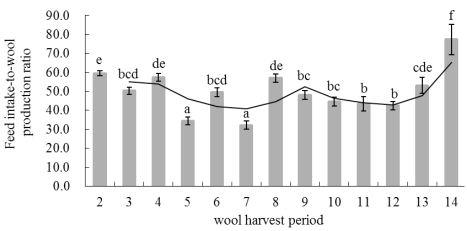

Figure 2: Feed intake-to-wool production ratio during different wool harvest periods. Feed intake-to-wool production ratio was higher during the 2nd and 4th periods than during the adult animal stage. The ratio was lower during the 5th, 7th, 11th and 12th periods than during the 8th and 13th periods, and the 14th period had the highest value (P<0.05). Values with different superscripts differ significantly at P<0.05.

Wool production performance of adult Angora rabbit

To rule out age effects, adult rabbits of similar characteristics were selected to assess differences in production performance among seasons. According to wool harvest date, average temperature and average relative humidity, the periods most representative of different seasons were chosen. Feeding and management information for different seasons is presented in Table 3.

Changes in wool production, feed intake-to-wool production ratio and daily weight gain in different seasons are presented in Table 4 and Figure 4, respectively. At a similar wool harvest interval, wool production (Table 4) was higher in spring and winter than in autumn, and was the lowest in summer (P<0.05). Concomitantly, feed intake-to-wool production ratio was lower in spring than in autumn and winter, and was the highest in summer (P<0.05). The daily weight gain (Figure 4) was higher in spring and autumn than in winter, and was the lowest in summer (P<0.05).

DISCUSSION

Angora wool production varies during the lifespan of the animal. Factors that affect wool yield include the interval between wool harvests length, harvesting methods (shearing *vs.* plucking), harvest number, animal sex, live weight and seasons, among others (Rochambeau and Thebault 1990). In China, the common traditional wool harvest intervals are 60, 73 and 91 d. However, the fibre length varies by harvest interval. In the present study, the evaluation of the optimum wool harvest interval and commercial lifespan of Angora rabbits is an attempt to improve Angora wool quality. To obtain the best quality fibre length, the required wool harvest interval was approximately 75 d, similar to the traditional harvest interval followed in China (73 d). This information is vital for the design of breeding strategies and for shearing planning to obtain quality wool.

It is crucial to evaluate the commercial lifespan for wool production, which directly affects economic profits in Angora farming. In our study, the performance of Angora rabbits over 3 yr with 14 wool harvest periods was evaluated. The results revealed that wool production decreased from the 13th period and was the lowest during the 14th period. Daily

Table 3: Feeding and management of Angora rabbits in different seasons.

Wool growth season	Wool harvest date (yy.mm.dd)	Age (months)	Average temperature (°C)	Average relative humidity	Wool harvest intervals (days)
Spring	13.03.25-13.06.08	14-17	21.4	58%	75
Summer	13.06.08-13.08.28	17-19	29.7	75%	74
Autumn	13.08.28-13.11.08	19-21	21.3	62%	72
Winter	13.01.09-13.03.25	12-14	5.3	80%	75

weight gain was negative during the 13th (28-31 mo) and 14th periods. The feed intake-to-wool production ratio, which represents an important factor when evaluating the economic profitability of Angora wool production, increased in the 13th period (53.2±4.3) and reached the highest value during the 14th period (77.3±7.9). Generally, feed intake-to-wool production ratio values should be <50. Values >60 are indicative that profits are considerably affected. For example, the average annual wool price in 2015 was 242 RMB yuan per kg (Li *et al.,* 2017), and feed price was 2.2 RMB yuan per kg (The foreign exchange rate of RMB to USD in 2015 was 0.1606). When the feed intake-to-wool production ratio increased from 42.4 (12th period) to 53.2 (13th period) and 77.3 (14th period), the profits were reduced by 23.7 and 77 yuan per kg wool, respectively. Furthermore, the average wool price in 2016 was 150 RMB yuan per kg. Taking other costs into consideration, once feed intake-to-wool production ratio values >50, there is no profit in Angora farming. Based on the results obtained in this study, the commercial lifespan of Angora rabbits was approximately 28 mo.

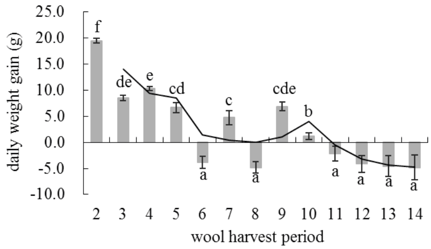

Figure 3: Daily weight gain during different wool harvest periods. Daily weight gain was higher or significantly higher (P<0.05) during the 2nd, 3rd, and 4th periods than during the 5th, 7th, 9th and 10th periods. However, daily weight gain was negative in 6th, 8th, 11th, 12th, 13th, and 14th periods (P<0.05). Values with different superscripts differ significantly at P<0.05.

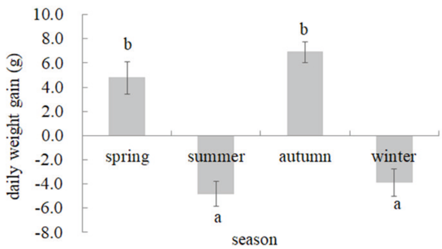

Figure 4: Daily weight gain of adult Angora rabbit in different seasons. At similar wool harvest intervals, daily weight gain of adult Angora rabbits was the lowest in summer (P<0.05). Values with different superscripts differ significantly at P<0.05.

Sheep wool production is affected by genetic and non-genetic (e.g., environmental) factors (Mirmahmoudi *et al.,* 2011; Winder *et al.,* 2010). High temperature and humidity conditions affect wool production in Malpura ewes (Sejian *et al.,* 2012). In the present study, wool production and daily weight gain were the lowest in summer, and feed intake-to-wool production ratio was the highest in summer. Studies have reported that stress due to high temperatures contributes to reduced growth performance and health of rabbits (Abdel-Khalek 2013; Marai *et al.,* 2002). Therefore, the summer adversely affected wool production, feed intake, live weight gain and feed efficiency of Angora rabbits.

The increased Angora wool production observed in spring and winter was concurrent with the reduced feed intake-to-wool production ratio found in this study. The reason might be that hair density is 20% to 30% higher in winter than in summer, as hair follicles are re-activated in autumn (Allain *et al.,* 2010). However, daily weight gain reached the highest values in autumn and spring, and the lowest values in summer and winter. Consequently, low ambient temperatures adversely affected the live weight gain of Angora rabbits. Previous studies have shown a strong correlation between body weight and wool production in Angora rabbits (Qinyu 1992; Singh *et al.,* 2011). In this study, strong correlations were observed in spring (higher wool production and daily weight gain) and summer (lowest wool production and daily weight gain). We also observed that season affected wool production, feed intake-to-wool

Table 4: Wool production performance of adult Angora rabbit in different seasons.

Season	Wool production (g)	Feed intake (g)	Feed intake-to-wool production ratio
Spring	292.0±13.8^{b}	9132.8±573.0^{a}	32.3±2.2^{a}
Summer	190.4±8.0^{a}	10610.3±265.0^{b}	57.0±2.3^{c}
Autumn	209.9±6.5^{a}	9903.1±325.7^{ab}	48.1±2.3^{b}
Winter	275.9±12.9^{b}	13294.4±534.9^{c}	49.5±2.4^{b}

^{a,b,c}Values in the same column with different superscripts differ significantly at P<0.05.

production ratio and daily weight gain of Angora rabbits. Spring, which has an average temperature and relative humidity of 21.4°C and 58%, respectively, provided the best conditions for Angora rabbits.

Wool production and wool quality vary during the lifespan of Merino sheep, especially with increasing age (Hatcher *et al.,* 2005). Previous studies have reported that total fleece weight from the first and second harvests of Angora rabbit wool is different to that obtained from subsequent harvests (Thebault *et al.,* 1992). Wool production was lower during the 2nd and 3rd periods compared to the 4th to 12th periods. Daily weight gain was higher in the 2nd, 3rd and 4th periods than during other periods. Therefore, age affected body weight and wool production in Angora rabbits. The harvest number dataset was separated into 2 subsets: one for each of the first 2 harvests and one for the 3rd to the 12th harvests (Rafat *et al.,* 2009). In French breeds, total weight of harvested wool increases rapidly up to the fifth harvest (Thebault & Rochambeau, 1988). Similar findings were obtained in present study, such as the highest wool production during the 5th period. Wool production rapidly decreased from 13th period and was the lowest during the 14th period. Daily weight gain was reduced from the 11th to the 14th periods. In contrast, the wool production in sheep increases up to a maximum at 3 yr of age, while wool quality traits decreased with age (Hatcher *et al.,* 2005). and the wool production gradually decreases with increasing age (Swan and Purvis 2000).

In conclusion, the results of the present study revealed that the optimum wool interval was 75 d, when the average fibre length reached 55.0 mm. Based on the wool production curve, the commercial lifespan of Angora rabbits was approximately 28 mo. We found that animal age had significant effects on wool production, feed intake-to-wool production ratio and daily weight gain. More importantly, wool production and daily weight gain were higher in spring and the lowest in summer. Concomitantly, feed intake-to-wool production ratio was lower in spring and the highest in summer. Therefore, wool production, feed intake-to-wool production ratio and daily weight gain were dependent on the season. Wool production decreased significantly in the summer. Spring provided the best conditions for Angora rabbit production.

Conflict of interest: We certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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