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Considerations for the design of a quail defeathering machine

(Pertimbangan untuk reka bentuk mesin untuk menanggalkan bulu burung puyuh)

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Key words: quail defeathering, mechanical defeathering

Abstrak

Puyuh burung yang tahan lasak dan berkhasiat berpotensi baik untuk ditingkatkan pengeluaran daging dan telurnya. Burung ini biasanya disembelih pada peringkat umur 5 minggu, dicelur dan bulunya dicabut dengan tangan. Seperti pengeluaran daging ayam, penghasilan daging puyuh secara komersil juga memerlukan mesin yang sesuai untuk menanggalkan bulunya. Satu formula telah dibentuk untuk mengira kelajuan pusingan dan garis pusat mesin agar proses menanggalkan bulu dapat dilakukan dengan berkesan. Formula ini telah dicuba dengan menggunakan data daya geseran gelincir antara bulu dengan tali sawat getah, kekuatan tarikan untuk menanggalkan bulu dari kulit dan berat burung yang sudah dicelur daripada ujikaji yang diadakan untuk mendapatkan maklumat tersebut. Kelajuan pusingan dan garis pusat mesin daripada kiraan didapati hampir sama dengan nilai yang diperoleh daripada mesin untuk menanggalkan bulu ayam yang telah diubah suai untuk digunakan pada burung puyuh.

Abstract

Quail, a hardy and nutritious bird, have good potential for increased production, both for meat and eggs. They are normally slaughtered at 5 weeks of age, scalded and defeathered by hand. As with chicken meat production, the commercialization of quail meat requires an appropriate defeathering machine. A formula for calculating the machine's rotational speed and diameter was derived for effective defeathering. The formula was tested by using data of the sliding frictional force, the force to pull individual feather off the skin and the weight of scalded birds from an experiment set up for that purpose. The calculated speed and diameter were found to be close to that obtained by actually defeathering quail in a modified chicken defeathering machine.

Introduction

Quail, a dual purpose avaian spesies, are hardy birds, seldom require routine vaccinations and medications. The earlier marketing age and high production rates, coupled with rather low floor area requirements and relatively lower investment capitals, make quail farming a viable business. Besides being easy and cheap to maintain, the quail provide supplementary incomes to farmers while serving as a valuable source of meat and eggs.

The common quail species domesticated in Malaysia is the Japanese quail *(Coturnix japonica)* which adapts well

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to the Malaysian environment. Rearing of quail consists of three stages i.e. brooding (0–2 weeks), growing (3–5 weeks) and laying (>6 weeks). Quail for meat are selected at 3 weeks of age by which the sexes can be identified. The males are distinguished by the cinnamon-coloured feathers on the upper throat and lower breast region. While females which are generally heavier, are characterized by light tan feathers with black stripes on the throat. Normally, the males will be selected and separated from the group for fattening until marketing age. Meat quail are best slaughtered at 5 weeks of age. They usually weigh around 140–145 g for maximum economic return and better meat quality (Panda 1990).

The live weight of a 6-week-old male quail is 175–195 g with an average of 185 g wet basis of which about 8% is feathers and blood. The dressed carcass is 92% of the wet weight while the evicerated carcass (ready-to-cook) is about 79% of the total weight (Seet 1992). The quail have to be scalded after slaughtering for defeathering. Quail at 5–8 weeks of age are scalded at 42 °C (quail's body temperature) for 2 min. The procedures involved in the dressing of quail are similar to that for chicken.

As with poultry (chicken) meat industry, the drudgery of defeathering quail manually is not conducive to large scale venture. It is imperative that a quail defeathering machine should be made available. The present chicken defeathering machine had been tried but the result was not satisfactory. With the increased demand for quail meat, there is a need for mechanical defeathering of quail. Some commercial farms had their own innovative designs but so far none is available in the market.

The present chicken defeathering machine is essentially a cylinder with a rotating base plate *(Figure 1)*, both are lined with regularly spaced rubber fingers. The base plate is a round disc wide enough to allow some space along the inner cylinder wall for lose feather passage through to an outlet chute at the bottom. The cylinder seats on a cubical housing in which an electric motor and belt drive is located. Water is introduced (manually) during the defeathering process along the inner cylinder side via a circular piping placed at the top. Cylinder capacity is normally for batches of five chicken, while bigger capacities are available. The main components are made from aluminum plates.

The design of a quail defeathering machine or the modification of the present chicken defeathering machine would benefit from a study of the physical parameters involved in the defeathering process. The main pulling force acting at the interface

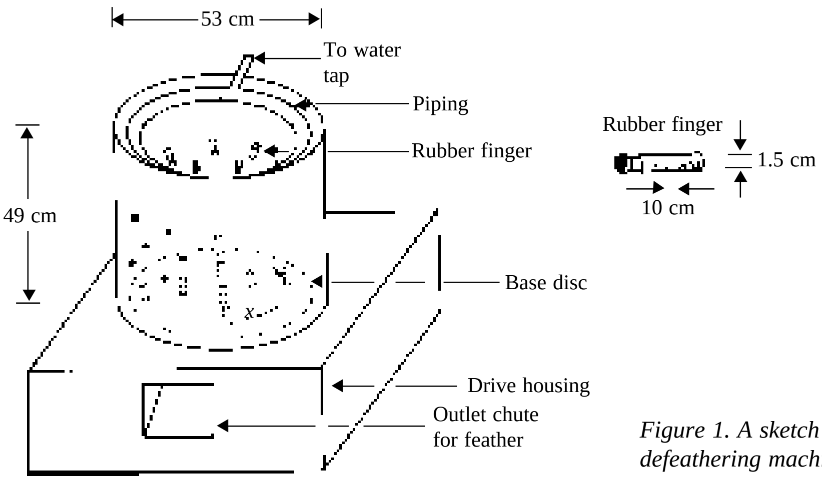

Figure 1. A sketch of a chicken defeathering machine

between a quail feather and rubber finger (which is currently used for chicken defeathering) is the centrifugal force which depends on speed, mass and the radius of the rotating drum, the skin retaining force and the interface sliding friction. The objective of the investigation was thus to find the relationship between the parameters and to recommend a specification (in terms of working drum speed and its radius) as a first approach for the design of a quail defeathering machine.

Theoretical relationship

It is assumed that the pulling force at the root of each feather while attached to the skin is solely due to kinetic friction between the rubber and feather, and gravitational effect is not considered as first approach. The parameters that are considered necessary to derive the relationship are

- pulling force (F),
- retaining force at root of feather (P),
- normal force on feather (N),
- coefficient of kinetic friction (μ),
- rotational speed (*x*),
- linear speed (v),
- drum radius (*r*),
- mass of bird's body (m) and
- the constant of a circle (π).

The interaction among these parameters are shown in *Figure 2*.

For an effective feather detachment, F >P. The centrifugal force is given as $(mv^2)/r = N$.

$\mu = F/N$ (by definition)

$F = \mu N = \mu(mv^2)/r$

where $v = 2x\pi r/60$ m/s

$= \mu\, m\, (2/60)^2\, x^2\, \pi^2\, r^2\, /r$

$= \mu\, m\, (1/900)\, x^2\, \pi^2\, r$

The feather is about to be detached at the moment when F = P

Thus, $\mu\, m\, (1/900)\, x^2\, \pi^2\, r = P$

$x^2 = 900\, P/(\pi^2\, \mu\, m\, r)$

$x = \text{sqrt}\, [\, 900\, P/(\pi^2\, \mu\, m\, r)]$

This formula have two unknowns, namely *x* and *r*.

Methods

A simple direct method was used for measuring the coefficient of sliding friction, their weights and the forces to detach the various feathers. The frictional properties of wet quail feather on rubber belt were measured as follows. A variable speed electric motor was used to drive a continuous 10 cm wide rubber belt running on two rollers *(Figure 3)*. It was driven at seven rotational speeds giving a set of seven linear contact speeds. A wing tip feather was placed on the belt between the rollers where the sliding force was measured by a spring balance for each normal load placed on the feather. The operation was done cautiously

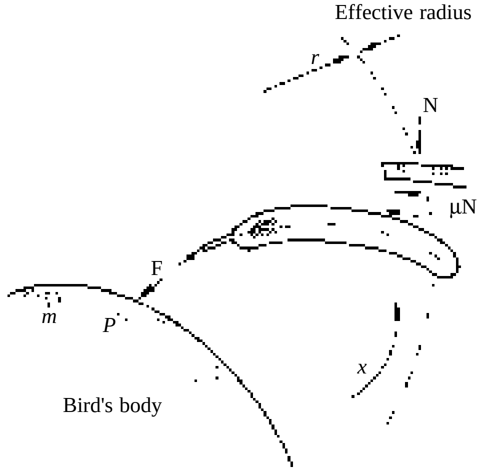

Figure 2. A diagram for the derivation of defeathering formula

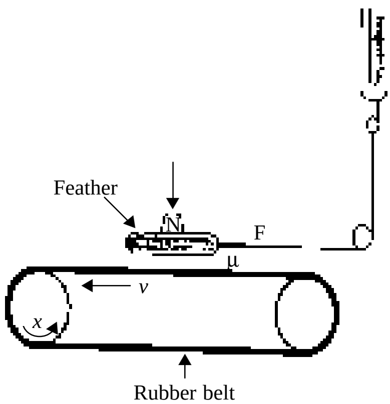

Figure 3. A schematic diagram of test-rig for measuring the coefficient of sliding friction of quail feather on rubber belt

to prevent the weight from coming into contact with the moving belts. Water was sprayed onto the belt and feather when they became dry.

Nine French quail (species) were dipped in water, allowed to drip and weighed. Feathers were pulled from each wing, the rear part and on the body where the feathers were categorized into long and short types. The pulling forces were measured by a spring balance via a string taped to each feather. The measurements were repeated.

Results

The coefficient of sliding friction at various belt rotational speeds and load on a feather are shown in *Table 1*. The result for wet body weight and spring balance reading is presented in *Table 2*. The mean coefficient of sliding friction, μ, is plotted in *Figure 4*.

The results *(Figure 4)* indicate that μ is high at low normal force and low at high normal force, it may have a finite adhesive strength due to surface tension at zero normal force. Theoretically, however, μ would tend to infinity as the normal force approaches zero by virtue of its definition which is pulling force divided by normal force; $\mu = F/N$. A computer program (in FORTRAN) was used to calculate x at most probable r, as in *Appendix 1*. Choosing the maximum body weight of 0.25 kg, mean

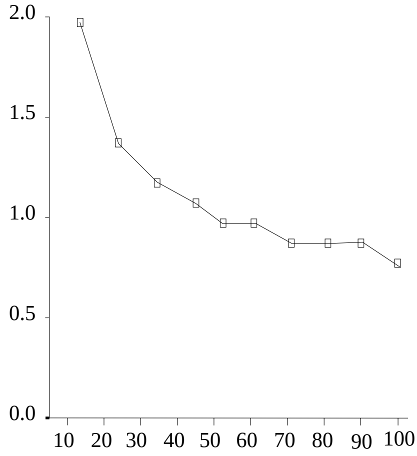

Figure 4. Mean coefficient of sliding friction of a wet quail feather on rubber belt

Table 1. Coefficient of sliding friction at various belt speeds and loads placed on wet feather

Belt speed (rpm)	Coefficient at various loads (N)										Overall mean μ
	10.7	21.2	31.7	42.1	52.5	62.8	72.9	82.9	92.9	102.6	
400	1.7	1.4	1.4	1.1	1.0	0.9	0.8	0.8	0.7	0.6	
600	1.9	1.5	1.1	1.2	1.0	0.9	0.8	0.8	0.7	0.7	
800	2.1	1.3	1.3	1.1	1.0	0.9	0.8	0.8	0.8	0.8	
1 000	2.1	1.3	1.3	1.3	1.1	1.1	1.0	1.0	1.0	1.0	
1 200	2.1	1.4	1.2	1.1	1.0	1.0	0.8	0.8	0.8	0.9	
1 400	2.1	1.4	1.3	1.1	1.0	1.0	1.0	1.0	1.0	0.8	
1 600	2.1	1.3	1.1	1.1	1.0	1.0	1.0	1.0	1.0	0.9	
1 840	1.9	1.2	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	
Mean	2.0	1.4	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.8	1.1
SD											0.35

Table 2. Ranges of wet body weights and spring balance readings of pulling force required to detach the various feathers

Body wt. (N)	Wing feather (N)	Rear feather (N)	Long body feather (N)	Short body feather (N)
1.5–2.7	6.0–9.4	1.5–4.5	1.8–3.1	0.3–0.8

Table 3. Predicted rational speed for defeathering quail at various μ, m and *r*

μ	m (kg)	P (N)	*r* (m)	*x* (rpm)
1.0	0.20	10	0.10	214
1.0	0.20	10	0.20	151
1.0	0.20	10	0.25	135
1.1	0.20	10	0.10	204
1.1	0.20	10	0.20	144
1.1	0.20	10	0.25	129
1.2	0.20	10	0.10	195
1.2	0.20	10	0.20	138
1.2	0.20	10	0.25	123
1.0	0.25	10	0.10	191
1.0	0.25	10	0.20	135
1.0	0.25	10	0.25	121
1.1	0.25	10	0.10	182
1.1	0.25	10	0.20	129
1.1	0.25	10	0.25	115
1.2	0.25	10	0.10	174
1.2	0.25	10	0.20	123
1.2	0.25	10	0.25	110

coefficient of kinetic friction of 1.1, and a maximum pulling force of 10 N, the required drum speed is 129 rpm at 20 cm radius and 115 rpm at 25 cm radius. The computer output at other drum radius, mass and μ is listed in *Table 3*.

The wider the radius, the lower is the required speed and as the coefficient of sliding friction decreases the speed needs to be faster. A lighter bird will require a slightly faster speed but weight is not as important as μ and *r*.

An experiment on a modified chicken defeathering machine (Sharif 1993) using a 26 cm radius drum indicated that the best speed was 125 rpm for 60 s., where it resulted in the best carcass quality, with 95% of the feathers removed, 5% of skin torn and less than 2% of wings and legs broken. The effective radius is expected to be less. The predicted speed is quite close to that measured by Sharif (1993); variations in the birds' weights, its coefficient of sliding friction and the effective radius may cause a slight deviation in the required speed. Other factors which should be considered in future works are probably rubber finger stiffness, its diameter, the spacing of fingers, the number of birds per job, the inclusion of water for cleaning (and may be for swirl or shock absorption) effect and the inclination of axis of rotation.

Conclusion

The formula does predict the required rotational speed very well. The most probable drum radius is 20 cm (130 rpm) to 25 cm (115 rpm) which are close to the radius of present chicken defeathering machine. Further work is necessary for the design of an efficient quail defeathering machine. Quail meat will continue to be a popular option to other poultry meats. Thus the evolution of an appropriate defeatherer is important.

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Appendix 1

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        PROGRAM FEATHER
*       A Program to optimise defeathering cylinder RPM
        CHARACTER*10 FNAME
        REAL P, PI, MU, AM, R, RPM
*
        WRITE (*, 90)
90      FORMAT ('Input file name - '\)
*
        READ (*, 91) FNAME
91      FORMAT (A)
*
        OPEN (3,FILE=FNAME)
****************************************************
        N = 1
        PI = ATAN(1.0)*4.0
        READ (3,99) P, MU, AM, R
10      IF (N .GE. 2) GO TO 98
99      FORMAT (/,4F10.2)
        GO TO 11
98      READ (3,100) P, MU, AM, R
100     FORMAT (4F10.2)
        IF (R .EQ. -1.0) STOP
11      RPM = SQRT((P*900.0)/(PI*PI*MU*AM*R))
        OPEN (4, FILE='RPM.RES', STATUS='OLD')
        WRITE (4,101) 'Radius = ',R, 'RPM = ', RPM
        PRINT '(1X,A,F7.1)','RPM = ',RPM
        N = N + 1
        GO TO 10
101     FORMAT (1X,A,F4.2,5X,A,F7.1)
        WRITE (*, 91) '      *************Siap***********'
        END
```