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No appreciable change in kangaroo carcase weights during cold storage: Implications for compliance with minimum harvest carcase weight restrictions

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No appreciable change in kangaroo carcase weights during cold storage: Implications for compliance with minimum harvest carcase weight restrictions

Abstract

The commercial harvest of kangaroos in Australia is regulated by various state government agencies. They control the number of kangaroos that can be harvested annually with the view to ensuring that the harvest remains ecologically and economically sustainable. In addition to controlling the harvest quotas, some agencies impose minimum weight restrictions on harvested animals, which may assist with maintaining viable breeding populations. However, harvesting usually occurs in remote regions and carcasses may be stored refrigerated for up to 10-14 d before being inspected for compliance with minimum weight restrictions. Consequently, there is concern that weight loss during cold storage, particularly in small carcasses close to the minimum limit, could lead to harvesters being wrongly prosecuted or fined for breaching the minimum carcase weight licence condition. We found that for two species of kangaroo, the large eastern grey kangaroo (*Macropus giganteus*; liveweight 30-70 kg) and the smaller red-necked wallaby (*M. rufogriseus*; liveweight 10-24 kg), carcase weight loss after 10 days cold storage was negligible. There was no significant effect of species on carcase weight change after 10 days cold storage and their pooled weight change averaged just -75.0 ± 18.0 g, or $0.35 \pm 0.08\%$ of initial carcase weight. This level of weight loss was significantly different from a hypothesised weight change of zero ($Z = -4.17$, $P < 0.001$). However, after an additional four days of cold storage, average weight change in the smallest carcasses (the red-necked wallabies) was not significantly different from zero ($Z = -1.65$, $P > 0.05$).

Keywords

Carcase dehydration, kangaroo, marsupials, harvesting

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

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1 **No appreciable change in kangaroo carcase weights during cold storage:**
2 **implications for compliance with minimum harvest weight restrictions.**

3

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16 Running Title: Kangaroo carcase mass during storage

17

18 Keywords: Carcase dehydration, kangaroo, marsupials, harvesting

1 **Abstract**

2 The commercial harvest of kangaroos in Australia is regulated by various state
3 government agencies. These agencies control the number of kangaroos that can be
4 harvested annually with the view of managing harvests for ecological and economic
5 sustainability. In addition to controlling the harvest quotas, some agencies impose
6 minimum weight restrictions on harvested animals, putatively maintaining viable
7 breeding populations. However, harvesting usually occurs in remote regions and
8 carcasses may be stored refrigerated for up to 10-14 d before they can be inspected for
9 compliance with minimum weight restrictions. Consequently, there is concern that
10 weight loss during cold storage, particularly in small carcasses close to the minimum
11 limit, could lead to harvesters could be wrongly prosecuted or fined for breaching the
12 weight restrictions. We found that for two species of kangaroo, the large eastern grey
13 kangaroo (*M. giganteus*; liveweight 30-70 kg) and the smaller red-necked wallaby (*M.*
14 *rufogriseus*; liveweight 10-24 kg), carcass weight loss after 10 days cold storage was
15 negligible. There was no significant effect of species on carcass weight change after
16 10 days cold storage and their pooled weight change averaged just -75.0 ± 18.0 g, or
17 $0.35 \pm 0.08\%$ of initial carcass weight; this was also not significantly different from a
18 hypothesised weight change of zero ($Z = -4.17$, $P < 0.001$). Initial carcass weight was
19 a significant co-variate for weight change after 10 days and larger carcasses lost more
20 weight than smaller carcasses, but again the absolute change was negligible (i.e. <
21 1.0% of initial weight). Moreover, after an additional four days of cold storage,
22 average weight change in the smallest carcasses (i.e. the red red-necked wallabies) was
23 not significantly different from zero ($Z = -1.65$, $P > 0.05$).

1

2 **Introduction**

3 Kangaroo harvesting in Australia is an established and burgeoning industry that
4 contributes around AUS\$230 million per annum to Australia's agricultural sector
5 (Kelly 2005). Traditionally, agriculturalists and pastoralists have viewed kangaroos
6 mainly as 'pests', but there is increasing interest in their viability as a commodity in
7 their own right, and particularly as a model for conservation through sustainable use
8 (Grigg 1989; Grigg 2002; Ampt and Baumber 2006). This is particularly so as
9 national and international markets for kangaroo products continue to expand, while
10 sheep and wool prices are declining (Ampt and Baumber 2006). Harvested kangaroos
11 are processed mainly for human consumption or for pet meat, in addition to
12 processing for skins/leather and related products. Additionally, kangaroos may offer
13 indirect economic returns through non-traditional sources like eco-tourism (Croft
14 2000; Higginbottom *et al.* 2004). Consequently, recent focus for kangaroo
15 management has shifted away from "pest-management" and toward sustainable
16 harvesting (Anon. 2007), thereby helping to ensure the viability of kangaroos as a
17 useful resource. Moreover, ecologically sustainable harvesting of kangaroos also has
18 implications for their contribution to total grazing pressures, particularly in arid and
19 semi-arid sheep rangelands (Olsen and Low 2006; Dawson and Munn, *In press*).

20 Five species of large kangaroo are harvested commercially on Australia's
21 mainland; the red kangaroo (*Macropus rufus*), the eastern (*M. giganteus*) and western
22 (*M. fuliginosus*) grey kangaroos, the common wallaroo/euro (*M. robustus*), and the
23 whip-tailed wallaby (*M. parryi*) (see Olsen and Braysheer 2000). In Tasmania, two
24 species of wallaby are also commercially harvested, the Bennetts wallaby (*Macropus*
25 *rufogriseus*) and Pademelon (*Thylogale billardieri*) (see Olsen and Braysheer 2000).

1 The commercial harvesting of kangaroos is managed at the State level by way of
2 kangaroo management plans (KMPs) or equivalent; governed by the Department of
3 Environment and Conservation (DEC) in New South Wales, The Department of
4 Environment and Heritage in South Australia, The Department of Conservation And
5 Land Management in Western Australia and the Queensland Parks and Wildlife
6 Service as as part of the Environmental Protection Agency in Queensland. Each
7 State's management plan regulates harvesting through the issuing of hunting tags for
8 commercial culling and also for pest mitigation.

9 Currently, most kangaroo populations are harvested at around 8-10% of total
10 population per year, which is well below the 10-20% allowable by most KMPs (Olsen
11 and Low 2006; Anon. 2007). This level of harvesting is also well below the maximum
12 levels predicted for sustainable management (McLeod *et al.* 2004). However, in
13 addition to controlling the total number of animals harvested, there is concern about
14 the age and size structure of the harvested populations (Wilson, 1975; Pople 2003;
15 McLeod *et al.* 2004). Therefore, most state plans impose strict minimum weight
16 restrictions for harvested animals. The setting of minimum weights aims to avoid
17 harvesting young animals, particularly females, so that they may have opportunity to
18 breed prior to culling, putatively maintaining population recruitment (Pople 2003;
19 Kelly 2005).

20 The set minimum carcase weight varies between states and according to
21 processing procedures for either human or pet food consumption. In NSW, where this
22 study was carried out, the minimum weight for carcasses dressed for human
23 consumption is 13 kg, and 12 kg for carcasses dressed for pet meat processing; human
24 consumption carcasses must retain the heart, liver and lungs for meat quality testing
25 prescribed by the Australian Standard for Hygienic Production of Game Meat for

1 Human Consumption (ARMCANZ 1997). In NSW, the DEC regularly inspects
2 harvested carcasses to check compliance with these minimum weight restrictions.
3 However, kangaroos are usually collected in remote and regional areas and may be
4 stored in field refrigerators, or chillers, for up to 10 days before being transported to a
5 meat processor (Greg Bates, Vacik distributors, pers. com). Consequently, carcasses
6 may be inspected some time after their initial slaughter and there is concern that they
7 may lose weight during cold storage, presumably through dehydration. Consequently,
8 harvesters could be wrongly prosecuted or fined for breaching the minimum weight
9 restrictions. Carcase weight change may also have implications for meat quality
10 (Wynn *et al* 2004). We therefore investigated the potential for carcase weight loss in
11 two species of kangaroo, the large eastern grey kangaroo (*M. giganteus*; average
12 liveweight 30-70 kg) and the smaller red-necked wallaby (*M. rufogriseus*; average
13 liveweight 10-24 kg). By using the smaller red-necked wallabies we were able fully
14 explore the potential for carcase weight change in animals that were below the
15 minimum weight allowed for commercially harvested kangaroos, thereby providing
16 data that encompassed the entire weight spectrum relevant for enforcing compliance.

17

18 **Methods**

19 Chiller storage conditions

20 The kangaroo carcasses used in this experiment were stored in a typical field chiller
21 (width 2.4 m; height 2.6 m, length 6.0 m). Chiller ambient temperature (T_a ; ± 0.5 °C)
22 and relative humidity (%RH; $\pm 0.6\%$) were measured hourly using a digital
23 temperature/humidity logger (Hygrochron iButton, model DS1923; Maxim Integrated
24 Products, CA USA). T_a and %RH were recorded along the centre of the chiller at the
25 front, mid and rear of the facility.

1

2 Animals and carcase weight change

3 The eastern grey kangaroos (n = 26 males; n = 14 females) used in this study were
4 collected by a professional shooter as part of a commercial harvesting operation in
5 southeastern New South Wales. The animals were collected over one night in
6 accordance with DEC NSW KMP (Anon. 2007) and relevant licenses issued under the
7 *National Parks and Wildlife Act 1974*. Carcasses were dressed at the point of harvest
8 and all carcasses were transported to our field chiller (cold storage unit) and
9 refrigerated by 0300 h (i.e. before the prescribed 2 h after dawn; ARMCANZ 1997).
10 Carcasses were dressed for pet meat processing (i.e. total organ evisceration,
11 decapitation and forepaws and feet removed; Fig 1). On entry to the chiller each
12 dressed carcase was weighed to the nearest ± 0.05 kg (Salter Scales, Lansvale, NSW)
13 to provide an initial 'hot' weight. Carcasses were hung suspended from the right leg
14 and in a manner that allowed air to flow over the entire animal surface and within the
15 thoracic cavity (Fig. 1), with the view of maximising potential for water loss by
16 dehydration.

17 The red-necked wallabies (n = 3 males; n = 5 females) used in this study were
18 collected as part of a separate study conducted by Munn *et al.* (unpublished). Red-
19 necked wallabies are not commercially harvested in NSW, but their average body
20 mass is at the low end of the typical weight range for the four large species of
21 commercially harvested kangaroo. Because all macropodids (kangaroos and
22 wallabies; family Macropodidae) have the same basic body shape and form, we used
23 the red-necked wallabies to investigate carcase weight changes in kangaroos that
24 would normally be well below the legal minimum weights allowed for the larger,
25 commercially harvested species (mainly the red, eastern and western grey kangaroos

1 and the euro/wallaroo). The red-necked wallabies were slaughtered by a lethal
2 intracardiac injection of sodium pentobarbitone (160mg kg^{-1}) between 0730 h and
3 0900 h on Day 1 of the experiment. Each carcass was exsanguinated and eviscerated
4 via a ventral incision before being carefully packed into plastic bags and stored cold
5 for transportation. The carcasses were then transported to our field chiller within 4.5 h
6 of slaughter. On arrival, the carcasses were dressed for pet-meat processing as per the
7 eastern grey kangaroos (above). Carcasses were weighed to the nearest ± 0.05 kg
8 (Salter Scales, Lansvale, NSW) and hung suspended by the right leg in a manner that
9 allowed air to flow over the entire animal surface and within the thoracic cavity.

10 On Day 1 of the experiment all carcasses were weighed (± 0.05 kg) between
11 1400 and 1500 h. Carcasses were then weighed at approximately the same time on
12 Days 2, 4, 5, 7 and 10. After ten days the eastern grey kangaroos were removed for
13 processing. The red-necked wallaby carcasses were stored for an additional four days
14 before a final weight was measured on Day 14.

15

16 Statistical analysis

17 We compared weight changes (absolute change in grams) between initial carcass
18 weights and those on Day 10 of cold storage in the red-necked wallaby and eastern
19 grey kangaroos using a General Linear Model (GLM). Assumptions for GLM were
20 tested using Kolmogorov-Smirnov test for normality and Levene's test for
21 homogeneity of variances. Initial ('hot') carcass weight was square root transformed
22 to achieve normal distribution and homogeneity of variances with respect to species.
23 However, because of the broad range in body weights for the male eastern grey
24 kangaroos (13.7 – 49.9 kg; $n = 26$) and their overrepresentation in the data compared

1 females (13.4 – 21.1 kg; n = 14), we could not achieve homogeneity of variances in
2 initial carcass weight for sex. Sex was therefore excluded as a factor from our study,
3 but is also unlikely to be important biologically as male and female kangaroos share
4 the same body shape and form (Fig. 1), with body weight being the primary difference
5 between sexes. Therefore, we investigated carcass weight loss after Day 10 of cold
6 storage using a GLM with species as a random factor and the square root of initial
7 carcass mass as covariate.

8 To determine whether smaller carcasses experienced increased weight loss after
9 additional cold storage, we measured carcass weights of the red-necked wallabies
10 after 14 days cold storage (i.e. Day 14 – initial weight; g). Gross carcass weight
11 change (g) for the red-necked wallabies by Day 10 and Day 14 were compared using a
12 paired, two-tailed t-test. Absolute carcass weight change (g) for the red-necked
13 wallabies on both Day 10 and Day 14 was also compared to theoretical weight change
14 of zero (g) using a one-sample Z-test (Zar 1999).

15 All stats were performed using Minitab for Windows. Data are presented as
16 means $\pm$ standard error of the mean (SEM). Differences were considered statistically
17 different at $p \leq 0.05$.

18

19 **Results**

20 Chiller storage conditions

21 The chiller maintained relatively constant T_a throughout the entire experiment, at an
22 average of -0.44 ± 0.08 °C (Fig. 2). Spikes in T_a were associated with carcasses

1 weighing sessions on Day 1, 2, 4, 5, 7, 10 and 14, but these periods each lasted less
2 than 1 h, and T_a was quickly restored (Fig. 1).

3 Average chiller %RH throughout the experiment was $98.0 \pm 0.3\%$. However,
4 chiller %RH was comparatively low on Day 1 of carcase storage, increasing from ca.
5 50% at 15:00 h (i.e. 12 h after the eastern grey carcasses entered storage, but
6 immediately following Day 1 weighing) and increasing to around 97% by 09:00 h on
7 Day 2 and 100% by 0:500 h on Day 3. Troughs in %RH were evident during carcase
8 weighing sessions on Day 1, 2, 4, 5, 7, 10 and 14 (Fig. 2).

9

10 Carcase weight changes

11 Carcase weight changes for the red-necked wallabies (Fig. 3) and eastern grey
12 kangaroos (Fig. 4) were relatively constant throughout the entire experiment (see
13 Table 1). Moreover, there was no significant effect of species on the level of carcase
14 weight change after 10 days of cold storage (Table 2). Initial carcase weight was not a
15 significant covariate for absolute carcase weight change after 10 days ($P > 0.05$; Table
16 2). Overall, when the kangaroo carcasses were pooled for species their average weight
17 change after 10 days was just -75.0 ± 18.0 g, or $0.35 \pm 0.08\%$ of initial carcase weight
18 (Table 1). Although small, this level of weight change was significantly different from
19 a hypothesised weight change of zero ($Z = -4.17$, $P < 0.001$).

20 There was no significant difference in the absolute weight change (g) of the
21 red-necked wallaby carcasses between Day 10 and Day 14 of cold storage, the values
22 being -37.5 ± 26.3 g and -75.0 ± 45.3 g, respectively (paired- $t_{(2)} = 1.43$, $DF = 7$; $P >$
23 0.05 ; Table 1). Moreover, the levels of carcase weight change (g) for the red-necked
24 wallabies by Day 10 and Day 14 of storage were each not significantly different from
25 zero (Day 10, $Z = -1.43$, $P > 0.05$; Day 14, $Z = -1.65$, $P > 0.05$).

1

2 **Discussion**

3 Putatively, weight loss from properly prepared kangaroo carcasses (i.e. eviscerated,
4 cleaned and exsanguinated) could result from residual body water/fluids evaporating
5 via the carcass' exposed surfaces; through the furred skin as post-mortem trans-
6 epidermal evaporation and from the thoracic and abdominal walls exposed by
7 evisceration. Therefore, it may be expected that smaller kangaroo carcasses,
8 particularly those close to the minimum legal weights prescribed for commercial
9 harvesting, could lose more weight during cold storage relative to larger carcasses
10 because of their higher surface area to volume ratios. However, we found that the
11 smaller carcasses were not more or less likely to lose weight compared with larger
12 carcasses. Indeed, the average weight change observed for the smallest of the kangaroo
13 carcasses (i.e. the red-necked wallabies) was not significantly different from zero after
14 10 or 14 days cold storage.

15 Generally, the macropodid marsupials (kangaroos, wallabies and rat
16 kangaroos) have the same basic body shape and form (Fig. 1). Therefore, that we
17 found no significant effect of kangaroo species on carcass weight changes after 10
18 days cold storage (Table 1) indicates that our results should be representative for most
19 harvested species spanning a live-weight range of 5-50 kg, but particularly for the
20 larger red and western grey kangaroos and for the euro/wallaroo. Overall, we found
21 that for carcasses prepared for pet meat consumption, the average weight changes after
22 10 days cold storage was negligible ($<0.1\%$ initial carcass mass). It is unlikely
23 therefore that significant weight loss could lead to borderline weight carcasses being
24 recorded as underweight as a consequence of dehydration during cold storage of up to
25 14 days. However, these results are applicable mainly to kangaroo carcasses prepared

1 for pet meat processing, and there are different considerations for carcasses prepared
2 for human consumption.

3 Carcasses that are prepared for human consumption are allowed a higher
4 minimum weight restriction to account for the retention of vital organs required for
5 food standards testing (ARMCANZ 1997). These organs include the heart, liver,
6 lungs and kidneys, which are generally high in water content, but it is difficult to
7 predict how these organs might change during cold storage. Nonetheless, for an
8 eastern grey kangaroo at a minimum allowable weight of 13 kg for human
9 consumption (Payne, N. pers. com), and assuming total organ dehydration of 100%
10 (which is very unlikely), the absolute maximum level of carcass weight loss that
11 could be expected would be 7.7% of initial carcass weight. Regardless, further
12 investigation is needed to fully appreciate how carcasses prepared for human
13 consumption may change during chiller storage.

14

15 **Conclusion**

16 Our results provide a useful guide for ensuring compliance with minimum weight
17 restrictions for harvested kangaroos. This is not only important for proper
18 management of kangaroo harvesting (Anon. 2007), but should assist harvesters in
19 improving and maintaining their skills at estimating live body weights in the field.

20

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5 *1974*. The red-necked wallabies were sourced from a separate project conducted by
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10 access to harvested carcasses and for use of a field chiller. Thanks to Dr Steve McLeod
11 and comments and improvements on earlier versions of this manuscript.

12

13

14

15

Table 1: Mean ($\pm$ SEM) change in kangaroo carcase weights after 10 and/or 14 days chiller storage (see text for statistical differences within species; values in parenthesis are as a proportion of initial carcase weight).

Species	Initial carcase weight (kg)	Change after 10 days (g)	Change after 14 days (g)
Red-necked (n = 8)	6.2 $\pm$ 0.5	-37.5 $\pm$ 26.3 (-0.60 $\pm$ 0.4%)	-75.0 $\pm$ 45.3 (-1.2 $\pm$ 0.7%)
Eastern grey (n = 40)	24.7 $\pm$ 1.5	-82.5 $\pm$ 131.8 (0.33 $\pm$ 0.5%)	-
Combined (n = 48)	21.6 $\pm$ 1.6	-75.0 $\pm$ 18.0 (0.35 $\pm$ 0.08%)	-

Table 2: General Linear Model for carcase weight changes for red-necked wallabies (n =8) and eastern grey kangaroos (n = 40) combined, with species as random factor and initial carcase weight (square root transformed) as a covariate.

Source	d.f.	F-ratio	P-value
Square Root Initial Carcase Weight	1	2.01	0.163
Species	1	2.82	0.331

Figure Labels

Figure 1: Kangaroo carcasses prepared for pet meat consumption and hung adequately spaced to maximise airflow across the furred surface and within the exposed thoracic cavity.

Figure 2: Average hourly chiller conditions for ambient temperature (Temp; °C) and relative humidity (RH; %) from Day 1 to Day 14 of cold storage.

Figure 3: Initial (Day zero) and daily weights (kg) for the red-necked wallaby carcasses measured on Day 1 – Day 14 of cold storage.

Figure 4: Initial (Day zero) and daily weights (kg) for the eastern grey kangaroo carcasses measured on Day 1 – Day 10 of cold storage.

Fig. 1:

Fig. 2

Fig. 3

Fig. 4