بسم الله الرحمن الرحيم

Sudan University of Science and Technology
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Cranometric and Morphometrics of Hare (*Lepus capensis*) from Abu Deliq and Almanagil Areas - Sudan.

قياسات جماجم وجسم الارنب البري من منطقتي ابودليق والمناقل في السودان.

BY
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A dissertation submitted in partial fulfillment of the requirements for the degree of master of science in wildlife management.

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DECLARATION

I declare that this research project is my original work. It is being submitted in partial fulfillment of the degree of Master of Science in Wildlife Management to the Sudan University of science and Technology. It has not been submitted for award of degree or for any similar purpose any other University.

Candidate: Ayat Yosuf Hassan Abdalla

Signature: **Date:**

DEDICATION

Verily, my prayer, my sacrifice, my living and dying are for Allah, the Lord of the Worlds

To my beloved mother and father

For their great efforts to help me complete this work, also I dedicate this humble work to my lovely brothers, sisters, friends and colleagues in the wildlife field for support and encouragements

ACKNOWLEDGEMENT

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ABSTRACT

In this study 46 hares were collected from two areas Abu-Delaig (n= 14) and AL-Managil (n= 32) .The main aims was to investigate Craniometrics and morphometrics of hares in the two geographic locations. Using digital Vernier with 0.01 mm accuracy for craniometrics and mastering table for the morphometrics. Hare meat was evaluated by the sensory method (color, flavor, tenderness and juiciness of the meat).

Tympanic bulla length is different ($P < 0.05$) among samples collected from the two geographic areas. Anterior nasal width (ANW), Mandible length (ML), Lower cheek-tooth row length (LCTRL), Upper cheek-tooth row length (UCTRL), Tympanic bulla width (TBL), Total length (TL), Foramina incisive width (FIW), and Width between facial tubercles (WFT) are larger ($P < 0.05$) for females compared with males. Compared with domestic rabbits, hares' meat was less Juicer ($P < 0.05$) as indicated by the sensory evaluation.

المستخلص

في هذه الدراسة جمعت 46 من الارانب البرية من ابودليق (ن=14) والمناقل (ن= 32). الاهداف الرئيسية لهذه الدراسة هو التحقق في قياسات الجمجمة والجسم في المنطقتين وذلك باستعمال الفيرنيا لقياسات الجمجمة والشريط المتري لقياسات الجسد. وعمل تقييم حسى للحوم الأرنب البري.

طول عرض الاذن كان مختلفا (P < 0.05) بين الأرانب التي جمعت من المنطقتين.اصغر عرض امامي؛ طول الانف الخارجي ؛ طول الانف الداخلي؛ عرض الانف الامامي؛ عرض الانف الخلفي؛ طول الفك السفلي ؛ انخفاض طول صف الاسنان؛ عرض الاسنان العلوي؛ ارتفاع الفك السفلي؛ طول الانيسيفوم؛ الطول الكلي؛ الطول الاجمالي؛ العرض بين درنات الوجه؛ عرض طبلة الاذن؛ عرض القاطع وطول الجسم كانت اكبر (P < 0.05) في الأنثى مقارنة مع الذكر. وقد أظهرت نتائج التقييم الحسي للحوم الأرانب البرية والمستأنسة أن ان العصرية في الأرانب البرية كانت اقل منها (P <0.05) في الأرانب المستأنسة.

ABBREVIATIONS

ANW	Anterior nasal width.
FIL	Foramen incisivum length.
ENL	External nasal length
UCTRL	Upper cheek-tooth row length.
FIW	Foramina incisive width.
LCTRL	Lower cheek-tooth row length.
FTL	Facial tubercle length.
MH	Mandible height.
INL	Internal nasal length.
ML	Mandible length.
PNW	Posterior nasal width.
TBW	Tympanic bulla width
PPW	Post palatal width.
PL	Palatal length.
RW	Rostral width.
PZW	Posterior Zigomatic width.
SFW	Smallest frontal width
TL	Total length.
TBL	Tympanic bulla length
WFT	Width between facial tubercles

CHAPTER I

1. Introduction

1.1 Hares

Hares belong to the order Lagomorpha which is represented by 13 genera, three families (Ochotonidae, Leporidae, and Prolagidae) and 93 species. The family Leporidae (hares, rabbits and jackrabbit) comprises 11 genera and 61 species. The hares *Lepus* L. is represented by 32 species (Wilson and Reeder, 2005).

They are placental mammals, plantigrade, terrestrial medium sized, slender with small head, big eyes and long ears, highly developed hind legs designed for running and jumping. Front limbs are equipped with five toes, and hind with four.. Common features are the presence of four incisors with no roots in the upper jaw and the lack of canines.

Hares move by jumping, pushing off with their strong hind legs and using their forelimbs to soften the impact on landing. They have prominent supraorbital foramina and nasal regions

1.2. The objectives of this study:

1. To determine morphometric variation of skull and body of hare *Lepus capensis* from Abudelaig and Almanagl areas.
2. To evaluate the sensory characteristics of hare meat compared with domestic rabbit meat.

CHAPTER TWO

2. Literature Review

2.1. Hares

Hares, members of genus *Lepus* (family Leporidae), are medium-sized mammals native to all the continents except South America, Australia and Antarctica. North American jackrabbits are actually hares. Species vary in size from 40 to 70 cm (16 to 28 in) in length and have long powerful hind legs and ears up to 20 cm (8 in) in length. Although usually greyish-brown, some species turn white in winter. They are solitary animals and several litters of young are born during the year in a form, a hollow in the ground amongst dense vegetation. The young are born fully furred and active. Hares eat plant material including stripping the bark off tree trunks. They are preyed upon by large mammalian carnivores and birds of prey (Smith, 2013).

2.2. Distribution

Hares distribution ranges from southern, eastern, and northern Africa, the Mediterranean, Israel, Arabian Peninsula, Iran, Pakistan, north India, southern Russia, to most of north China (Flux and Angermann, 1990; Hoffmann and Smith, 2005). The Cape hare is not only a widespread species, but also a polytypic taxon (comprises about 80 subspecies), and all these groups need revision. Hence, determining the phylogenetic position of hares that are grouped under *L. capensis* is hard because of its polytypic nature and conflicting results were found by different authors. Accordingly, hares once grouped under L. capensis are presently classified into different taxa (Azzaroli-Puccetti 1987; Flux and Angermann, 1990; Hoffmann and Smith, 2005). For instance, partitioned Cape hares (*L. capensis*) in South Africa in two species, namely *L. capensis* (confided to Cape Province) and *L.* centralis distributed in the remaining ranges of Cape hares based on intensive skull morphometric data *(*Palacios et al., 2008). (Klappenbach and Laura 2013).

Like other herbivorous lagomorphs, hares have to deal with a bulky diet in which the cell walls are composed of cellulose, a substance which mammalian digestive enzymes are unable to break down. Despite this, hares have developed a way of extracting maximum nourishment from their diet. First, they bite off and shred plant tissues with their incisors and then they grind the material with their molars. Digestion continues in the stomach and small intestine where nutrients are absorbed. After that, certain food remains get diverted into the caecum, a blind-ended pouch. Here, they are mixed with bacteria, yeasts and other micro-organisms that can digest cellulose and turn it into sugar, a process known as hindgut fermentation. Other fecal matter passes along the colon and is excreted in the normal way as small, dry pellets. About four to eight hours after the meal, the contents of the caecum pass into the colon and are eliminated as soft, moist pellets these are immediately eaten by the hare, which can thus extract all the remaining nutrients in the food (Exploring *a Rabbit's* 2013).

Hares breed several times a year and produce large litters. The antiracial young of hares, called kittens, are born naked and helpless after a short gestation period and the mother can become pregnant again almost immediately after giving birth. The mothers can leave these young safely and go off to feed, returning at intervals to feed them with their unusually rich milk. In some species, the mother only visits and feeds the litter once a day but the young grow rapidly and are usually weaned within a month. Hares live above ground and their litters, containing leverets, are born in "forms" concealed among tussocks and scrub. They have a strategy to prevent predators from tracking down their litter by following the adults' scent. They approach and depart from the nesting site in a series of immense bounds, sometimes moving at right angles to their previous direction (Burton, 1971). The young are precocial and a small number are born after a longer gestation period, already clad in short fur and able to move around *(*Smith, 2013). Hares are generally solitary species. They rely on their long legs, great speed and junking gait to escape from predators. Despite these defensive devices, hares form an important part of the diet of carnivorous mammals and birds of prey (Klappenbach and Laura 2013).

2.3.1. *Lepus capensis*

Lepus capensis is probably the most abundant *Lepus* species in Africa, with densities ranging from 4.7–24.8 hares/ km² in South Africa alone (Happold, 2013a).

It has an extensive but scattered distribution across southern, eastern and northern Africa, occurring in Mediterranean, Coastal, Sahel, Savannah and southern African biotic zones (Palacios *et. al.,* 2008; Happold, 2013a). However, further taxonomic delineation will improve our understanding of its geographical distribution. Currently, there is a gap in its distribution as it does not occur in Malawi, southern Tanzania, northern Zimbabwe and parts of Mozambique (Happold, 2013c). It is restricted to no forested regions (Boitani et.al., 1999).

2.3.2. Habitats and Ecology

Lepus capensis is very adaptable and lives in a wide variety of grassland and open habitat, avoiding only bushy or closed habitats (Happold, 2013c; Boitani *et al.,* 1999). It is widespread throughout Nama-Karoo and Succulent Karoo biomes, and occurs in parts of the Grassland and Savannah Biome in southern Mozambique (Skinner and Chimimba, 2005). Free-ranging Cape hares were found to have home ranges of 6.459 ha and 8.25 ha for males and females, respectively, which are defended in some portions, but may overlap at the fringes (Wessels, 1978). However, home range size is known to vary depending on habitat type (Flux and Angermann, 1990). This species feeds both by browsing and grazing, and can survive successfully without a continued supply of surface water by relying on forage source of moisture (Skinner and Chimimba 2005). They are usually solitary, except when females are in estrus. Reproduction is seasonal with a peak in contraception occurring during July and December when three young are usually born (Taylor 1998a, 1998b). And may have up to four litters per year (Wessels 1978) The gestation period lasts approximately 42 days Flux and Angermann (1990) noted that up to eight litters per year are possible.

Modified landscapes, such as those overgrazed by livestock, are suitable habitats for *Lepus capensis* (Flux and Angermann 1990). Similarly, *Lepus* species are attracted to cultivated areas and gardens (Happold 2013a). The distributional limits of *L. capensis* and *L. saxatilis* overlap somewhat (Skinner and Chimimba 2005). The former extends into arid, open regions while the latter is confined to areas of grass cover within savannah woodland and scrub and adapts easily to agricultural landscapes *(*Kryger et al. 2004b). All *Lepus* species prefer green grasses (Skinner and Chimimba, 2005) although *L. capensis*, prefer denser vegetation and higher latitudes (Flux and Angermann, 1990). The diet of this species varies with habitat type, and like other *Lepus* species *(*Flux and Angermann, 1990).

2.3.3. Conservation:

Lepus species are occurring within numerous protected areas, including both formally and privately protected areas, which calls for sustainable utilization of this species (Kryger et al., 2004a); for they may constitute a low-carbon source of protein and may economically benefit local communities and landowners (Asibey, 1974). The development of conservancies to protect appropriate habitats for local subspecies and forms is recommended.

2.3.4. Use and Trade:

Lepus species are hunted recreationally for sport, bush meat and fur at a subsistence level. However, this is not expected to have a substantial effect on the population. Both *L. capensis* and *L. saxatilis* were listed as species utilized for traditional medicine in South Africa, as they are believed to have medicinal or curative properties *(*Maliehe, 1993; Ntiamoa-Baidu, 1997).

2.3.5. Threats

Across their range, *Lepus* species are threatened by habitat loss and fragmentation as a result of urban sprawl, agricultural encroachment, commercial plantations, and infrastructure development for tourism (Drew et al., 2004; Kryger et al., 2004a). Additionally, these species are threatened by hunting pressure through both recreational sport hunting, as well as subsistence hunting for bush meat and fur. While agricultural and urban expansion may not necessarily cause direct declines, they may increase hunting pressures. Hunting pressure is likely to cause local subpopulation declines. For example, drastic population declines have been observed in KwaZulu-Natal, specifically in Harding and Port Shepstone in southern KwaZulu-Natal (*Kryger et al. 2004a*).

2.4. Skulls Characterization

The term skull has been used to describe the entire skeleton of the head. The skull is both a highly modular and a highly integrated structure. The skull is divided into three primary units, the face, neurocranium and basicranium. The brain case provides protection for the brain and opening for cranial nerve connections, the bone of the face provides a location and protection for the organs of special senses and openings for the digestive and respiratory system.

The skull is a mosaic of many bones, mostly paired, but some median and unpaired, that fit closely together to form a single rigid construction (Reece, 2009; Dyce, 2010). The shape of the head and skull influence the dynamic of the locomotion and balance. The specific characteristics of a skull often reflect the animal methods of feeding and effect on the muscle of mastication (Olude and Olopade, 2010). Skulls differ largely, not only between different species and breed but also between individuals of same breed, age and sex (Koing and Liebich, 2004). Craniometric studies of the skull of different animal species continue to be a growing area of applied research, the values obtained from such studies, apart from being important in morphological fields, improve clinical diagnosis and regional anesthesia of the head and treatment of cranial skeletal disorders (Shawulu et al., 2011; Yahaya et al., 2011). Historically, subspecies of hares were classified based on the morphological features of the skull and teeth (Suchentrunk et al., 2003; Palacios et al., 2008). Besides morphometric, application of molecular methods over the last years contributed also in elucidating the systematics and distribution of subspecies.

2.4.1. Skull Measurements

The skull of leporids (rabbits and hares) is highly transformed, typified by pronounced arching of the dorsal skull and ventral flexion of the facial region space, and describes a small proportion (13.2%) of overall cranial shape variation in the clade (Brian Kraatz and Emma Sherratt, 2015). Evolutionary relationships and taxonomy of species belonging to the genus *Lepus* are controversial (Flux and Angermann, 1990; Hoffmann, 1993). Although many hypotheses have been proposed to clarify the specific or subspecies status of European, Asian and African hares, taxonomists have not agreed on nomenclature (Hoffman, 1998). Craniometric differentiation was assessed by analyzing skulls belonging to 3 different species of the genus *Lepus* (*L.europaeus*, *L. corsicanus*, and *L. capensis*): all measurements differed significant among three genera. However, no significant differences resulted between sexes (Riga, et al .2001). Pintur et al., (2014) found significant variations in skull measurements between hares sampled on the island of Vir and in continental north-west Croatia while, no significant for both sites in Craniometric measurements according to sex. According to Fatima, et al (2016), Skull parameters from east and west of the Nile were similar, but greater than their counterparts between the Blue Nile and the White Nile tributaries of the Nile.

Tympanic bulla width was wider in males compared with females. It was concluded that hares from the three regions are likely not conspecific but are sexually dimorph.

2.5. Body measurements

James (1970) suggested that body size variation is related to a combination of climatic factors, mainly moisture and temperature, and that small body size is associated with hot and humid conditions and larger size with cooler and drier conditions. The body size is better correlated with basal metabolic rate, cost of transport, dominance in a community, success in mating, size and type of food, and competition (Dayan et al., 1989).

Fatima et al (2016) study determine morphological discrimination in body measurements of *Lepus capensis* collected from different geographic regions of Sudan, in order to test if the morphological results are consistent in the different regions. It was found that hares from Western region had longer tails than those between the White and Blue Niles, and those from the Eastern region. Also, females were heavier than males, this is indicating sexual dimorphism. Although (Riga, et, al, 2001) took tail, ear, head body and hind foot

from fresh adult animals collected during hunting activities or restocking operations measurements reported on the museum labels, he found that females were taller than males. He recommended such measurements should not be considered to avoid bias due to different measuring methods.

The body and skull sizes of animals are usually considered positively correlated with a decrease in temperature; this is known as Bergmann's rule (Meiri *et al.*, 2004).

2.6. Sensory of hares and rabbit meat

Sensory characteristic of the color, flavor, tenderness, and juiciness of rabbit meat, is attributed to the age and sex of the wild bunny, the type of food that they feed on its, its chemical composition and the amount of physical stress it is exposed to It is known than females, this color indicates that the color of the meat for the same animal is different form one muscle to other. Also, the flesh color of the older animal is deeper because the level of myoglobin increases with age (USDA, 2006).

Panel's tastes are widely used in the meat industry for assessing eating quality, and often used to monitor product quality, usually to comply with customer requirements or company quality control procedures, but properly conducted taste panels have many other potential uses (AHDB, 2010).The meat means all striated muscle tissues that come about naturally, together with connective tissues lax, fibrous, cartilage, fat, bone and nerves, blood vessels and lymph nodes. The proportion of different tissues of meat depends on the species, breed, age, sex, state of fattening and carcass region (Blasco and Piles, 1990). In recent years, consumer interest in specialty products derived from free-range or organic production systems has steadily increased in Europe and in other parts of the world. Customers who prefer rabbit specialty products have expectations of higher quality meats derived from these systems and higher standards of animal welfare (Maertens and Van Oeckel, 2001;Pla 2008;Jekkelet al.,2010). Several studies have reported that housing systems can affect body weight, carcass traits and sometimes meat quality (Mertens and VanOeckel, 2001;Pla 2008).

CHAPTER THREE

3. MATERIALS ANDMETHODS

3.1. Study Area:

This study was conducted in two different areas, Abu delaig at Khartoum state and Al Managel at Gezira state in Sudan in 2018.

3.1.1. Abu delaig **Area**

Abu delaig area is located east of the Nile about 150 kilometers east of Khartoum.

Abu Deliq area is leveled land, lacking mountains and hills that characterized the plain lining and made it in the autumn season bright green carpet. The flat plain also helped in the establishment of large-scale agricultural projects (https://en.wikipedia.org/wiki/Sudan)

3.1.2. Al Managel Area:

Al Managel area is located in the Gezira state at a height of 412 meters (1351 feet) above sea level. It is about 156 kilometers (96.9 miles) away from Khartoum. It is in the middle of an agricultural project that carries its name which is an extension of the Gezira agricultural Scheme in Sudan. The locality of the Al Managel is between Latitudes 23.30- 33.15 and longitudes 13.45-14.15 South -west of the Gezira of Sudan. It is bordered on the west and southwest by the White Nile State and the south-east of Sennar State with an area of about 6250 Km^2.

The topography of the area is characterized by the presence of granite rocks and sand rocks. The main rocks are dominated by the southwestern region of the local area, where the lands of the Jamusi and Maturi administrative units are covered. The Nubian sand rocks cover the northern and eastern parts of the local area, including Al-Mnagel, Al-Huda and Karimat.It is located in the southeast part of the governorate of the Movable Highlands, in an area of 260,000 feddans in three administrative units: Al-Jamoussi unit, the city of transport units and the rural transport unit. The plateau is a natural boundary of irrigated land in the Al-Jazeera agricultural project, interspersed with two hills.

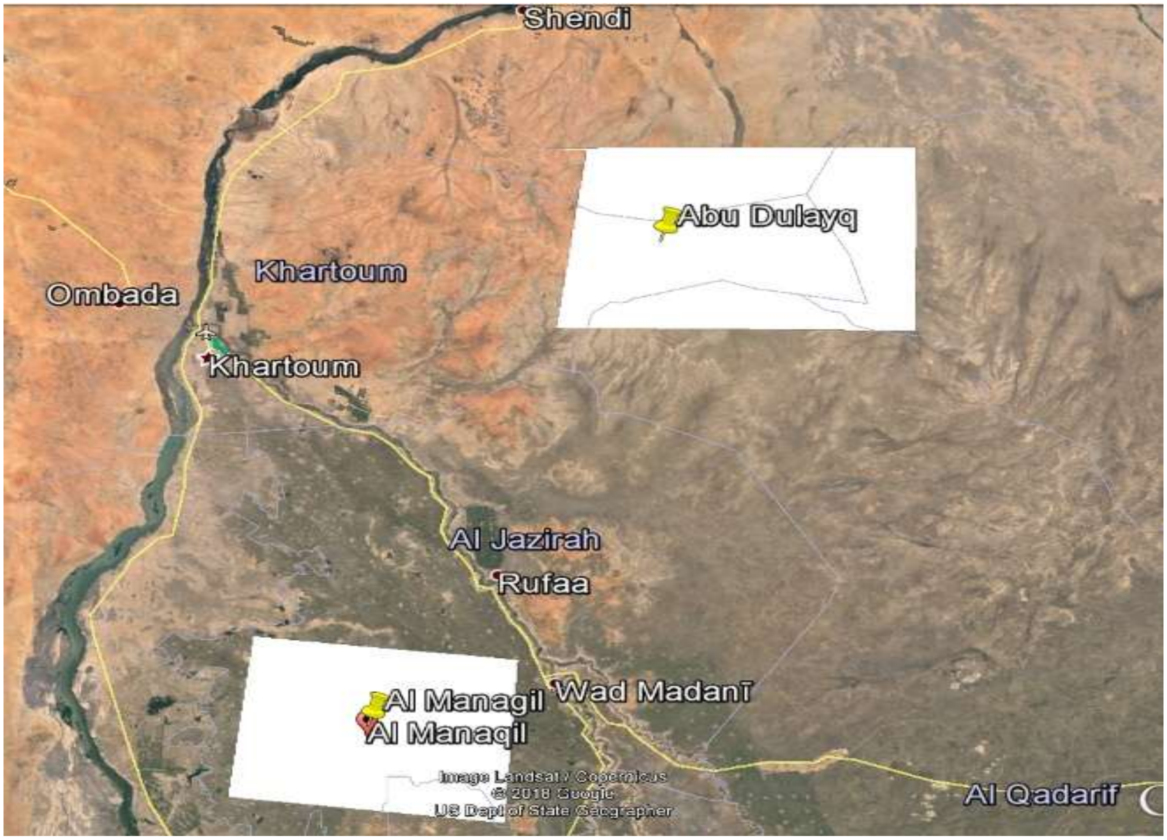


Figure 3. 1: The sample collection areas, Sudan. Source**:** Google Earth Program

3.3. Samples Collection

Total of 46 hares were collected under permission of General Directorate of Nature Protection and National Parks from Gezira and Khartoum state in 2018 (Fig.3.1). The lab work done for all specimen collected was in Department of Fisheries and Wildlife Science College of Animal Production Science and Technology, Sudan University of Science and Technology. Forty six hares were collected, samples sizes were 14 hares from Abu delaig, 32 from AL-Managil (Table 3.1).

Table 3.1: Sample sizes of hares collected form two areas in two states in Sudan**,** 2018

States	Location	Females	Males	Total
Khartoum	Abu Deliq	6	8	14
Gezira	AL-Managel	20	12	34

3.4. Body measurement

Four body measurements were taken: total body length (TBL), tail length (TL), hind foot length (HFL) and ear length (EL) immediately after the animals were collected during field work, using a tape according to Harrison and Bates, (1991: Anthony and Robert (1979). The tail length was measured as the distance from the base of the tail to its tip, ear length the distance between the tip of the ear and the white base.

3.5. Skulls measurement

Eighteen skull measurements was taken, using digital calipers with an accuracy of 0.01 mm**.** The measurements were: the total length (TL); anterior nasal width (ANW); external nasal length (ENL); foramen incisivum length (FIL); foramina incisive width (FIW); internal nasal length (INL); lower cheek tooth row length (LCTRL); upper cheek-tooth row length (UCTRL); mandible height (MH); mandible length (ML); palatal length (PL); posterior nasal width (PNW); post palatal width (PPW); posterior zigomatic width (PZW); rostral width (RW); smallest frontal width (SFW); tympanic bulla length (TBL); and width between facial tubercles (WFT), a corroding to Palacios (1996).

3.6. Evaluation the sensory characteristics of hare meat

The sensatory technique which were includes., tenderness, juiciness, color and flavor are the three major attributes that determine eating quality. (Ahdb,2010). Samples of meat were prepared after rabbits and hares were killed, put in freezes to which ingredients (potatoes, white peppers, milk powder, salt) were added. The ingredients were then mixed well and lapelled for tasting .Assessors marked the category that best described the sample (scores of 1 to 8 were assigned to the various categories, the extremely tender being 8 (Table 3. 2). Forty-seven questioners were distributed for volunteered panelists to examine the samples.

Table 3.2: Category scales for evaluating the eating quality of hares and rabbit's meat in Sudan, 2018.

Tenderness	**Juiciness**	**Flavor**	**Color**
Extremely tender	Extremely juicy	Extremely strong	Extremely color
Very tender	Very juicy	Very strong	Very color
Moderately tender	Moderately juicy	Moderately strong	Moderately color
Slightly tender	Slightly juicy	Slightly strong	Slightly color
Slightly tough	Slightly dry	Slightly weak	Slightly weak
Moderately tough	Moderately dry	Moderately weak Very	Moderately weak Very
Very tough	Very dry	Very weak	Very weak
Extremely tough	Extremely dry	Extremely weak	Extremely weak

CHAPTER FOUR

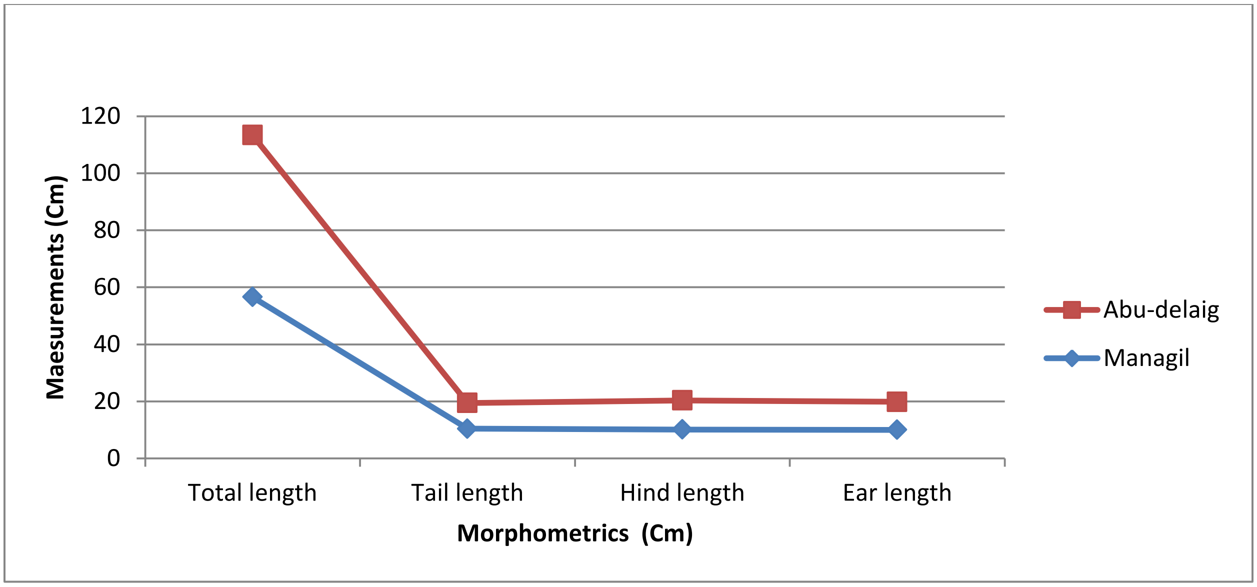
4. RESULTS

4.1 Morphometrics A according to the Geographic Areas

Total length, Hind foot length and ear length were similar (P > 0.01) except the tail length which was longer (P < 0.01) for hares in Managil.

Table (4.1): Morphometrics collected from Managil and Abu delaiq from Sudan in 2017.

Areas	Morphometrics **(cm)**			
	Total length	**Tail length**	**Hind length**	**Ear length**
Managil (n=32)	56.56±3.44	10.42±1.06	10.13±0.46	10.02±0.47
Abu-delaig (n=14)	56.79±2.52	9.04±1.23	10.19±0.80	9.82±0.50
Sig.	NS	**	NS	NS
**=significant differences at P<0.01				



Figure(4:1) Morphometrics of *Lepus ca pensis* collected from two areas

4.2. Craniometrics:

Measurements of the *Lepus capensis* skull comprising the anterior nasal width (ANW); external nasal length (ENL); foramen incisivum length (FIL); foramina incisive width (FIW); facial tubercle length (FTL); internal nasal length (INL); lower cheek tooth row length (LCTRL); upper cheek tooth row length (UCTRL); mandible height (MH); mandible length (ML); palatal length (PL); post palatal width (PPW); posterior zigomatic width (PZW); rostral width (RW); smallest frontal width (SFW); tympanic bulla length (TBL); tympanic bulla width (TBW); and width between facial tubercles (WFT) are shown (Table 4.2). All skull measurements in Managil and Abudilaiq localities were not different ($P > 0.051$) except TBL ($P < 0.050$).

Table (4.2): Craniometrics of hares collected from Managil and Abu delaiq from Sudan in 2017.

Areas	**Craniometrics (cm)**								
Locations	**SFW**	**ENL**	**INL**	**ANW**	**PNW**	**ML**	**LCTRL**	**MH**	**UCTRL**
Managil (n=32)	11.90±0.82	32.93±1.84	27.15±1.81	10.35±1.37	21.26±1.71	56.01±3.41	13.73±1.43	35.54±2.58	13.20±1.50
Abu-delaig (n=14)	11.43±0.86	32.77±1.32	26.13±1.25	9.61±0.79	20.92±1.10	55.11±1.98	13.78±1.71	34.92±2.42	12.51±1.37
Sig.	NS	NS	NS	NS	NS	NS	NS	NS	NS
NS=No significant differences									

ABBREVIATIONS

ANW	Anterior nasal width.
ENL	External nasal length
UCTRL	Upper cheek-tooth row length.
LCTRL	Lower cheek-tooth row length.
MH	Mandible height.
INL	Internal nasal length.
ML	Mandible length.
PNW	Posterior nasal width.
SFW	Smallest frontal width

Continue to table (4.2): Craniometrics of hares collected from Managil and Abu delaiq from Sudan in 2017.

Areas	Craniometrics (cm)								
Locations	**TBL**	**PZW**	**PPW**	**TL**	**PL**	**FIL**	**FIW**	**RW**	**WFT**
Managil (n=32)	12.09±1.05	36.59±2.10	7.43±0.71	77.82±5.10	32.47±1.53	20.35±1.60	9.20±0.40	21.50±0.82	32.52±2.15
Abu-delaig (n=14)	11.43±0.78	35.60±1.42	7.30±0.54	77.01±2.69	32.15±1.16	20.33±1.54	9.05±0.37	21.00±1.02	31.77±0.95
Sig.	*	NS	NS	NS	NS	NS	NS	NS	NS
	*=significant differences at P<0.05 NS=No significant differences								

ABBREVIATIONS

FIW	Foramina incisive width.
FTL	Facial tubercle length.
PPW	Post palatal width.
PL	Palatal length.
RW	Rostral width.
PZW	Posterior Zigomatic width.
TL	Total length.
TBL	Tympanic bulla length
WFT	Width between facial tubercles

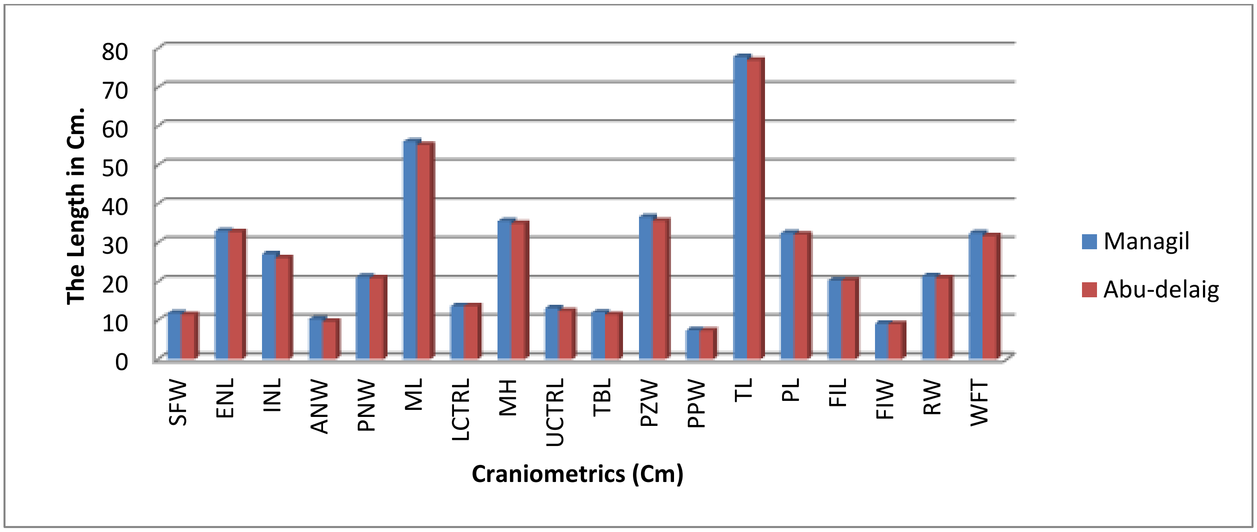


Figure 4.2: Craniometrics for Managil and Abu delaiq in Gazeira and Khartoum states, respectively in 2017

4.3. Sex Craniometrics:

As shown in table 4.3, ANW, TBL, TL and WFT were longer for female ($P < 0.05$) as were MIL, LCTRL, MH, UCTRL and FIW ($P < 0.01$)

Table 4.3 : Sex Craniometrics (cm) in the Managil and Abu delaiq, Sudan in 2017

Measurements	Male (n=28)	Female (n=16)	Significant
SFW	11.75±0.88	11.95±0.67	NS
ENL	32.75±1.80	33.38±1.32	NS
INL	26.61±1.45	27.59±1.81	NS
ANW	9.94±0.90	10.81±1.26	*
PNW	21.46±1.47	20.86±1.59	NS
ML	55.03±2.56	57.49±3.13	**
LCTRL	13.52±1.27	14.69±0.55	**
MH	34.93±2.00	36.92±1.83	**
UCTRL	12.70±1.11	13.88±1.45	**
TBL	11.71±0.83	12.41±1.06	*
PZW	36.32±1.38	36.75±2.39	NS
PPW	7.42±0.41	7.54±0.78	NS
TL	77.47±2.48	79.71±3.43	*
PL	32.53±1.27	32.51±1.29	NS
FIL	20.47±1.35	20.47±1.77	NS
FIW	9.10±0.27	9.39±0.34	**
RW	21.31±0.61	21.65±1.11	NS
WFT	31.96±1.15	33.34±2.26	*
**=significant differences at P<0.01			
*=significant differences at P<0.05			
NS=No significant differences			

4.4 Sex Morphometrics :

As shown in Table 4.5, body measures were similar ($P > 0.01$) for males and females except the total length, females are longer ($P < 0.01$) than the males (58.06±3.07 vs 56.04±2.76) cm.

Table 4.4: Morphometrics (cm) for the sexes

Parameters	Males	Females	Significant
Total length	56.04±2.76	58.06±3.07	*
Tail length	9.89±1.24	10.23±1.39	NS
Hind length	10.14±0.66	10.17±0.43	NS
Ear length	9.95±0.51	9.97±0.46	NS

4.5. The panel test of hares and rabbits meat:

The results of panel test for hares and rabbits are shown in table (4.6). There was a significant differences ($p < 0.05$) according to juiciness which hare represented, whereas there was no significant differences ($p>0.05$) among other parameters for hare and rabbit.

Table 4.5: The panel test of hares and rabbits:

Panel test parameters	Type of meat		Significantly
	Domestic rabbit	Wild hare	
Color	6.02±1.58	5.55±1.77	NS
Texture	5.62±1.74	5.21±2.04	NS
Flavor	5.81±1.85	5.64±1.90	NS
Juiciness	5.34±.83	4.98±1.65	*

Sensory assessments (Color, Tenderness, Flavor and Juiciness for rabbits and hares are summarized in Table 4.7 and depicted in figs. (4.7).

Generally, participants scored more percentage of colors of rabbit meat compare to hares' meat (Table 4.7, Fig. 4). This applies also to meat tenderness (Fig. 5) but to a lesser extent.

As far as flavor is concerned, rabbit's meat scored a high percentage of moderately strong flavor (Fig. 6) compared with rabbit's meat. The same situation applied to Juiciness test (Fig. 7).

Table 4.6: Percentages of sensory assessment of hare and rabbit meat

Factors	Color		Tenderness		Flavor		Juiciness	
	Rabbits	**Hares**	**Rabbits**	**Hares**	**Rabbits**	**Hares**	**Rabbits**	**Hares**
Extremely	17	6.3	10.6	14.8	19	21.2	12.5	8.5
Very	25.	36	27.6	14.8	8.5	14.8	14.8	10.6
Moderately	29.7	14.8	6.3	21.2	8.5	23.45	23.4	14.85
Slightly	10.6	17	8.5	12.7	10.6	10.6	21.2	27.6
Slightly	8.5	6.3	19	14.8	17	10.6	8.5	17
Moderately	4.2	17	6.3	10.6	27.5	8.5	10.6	14.8
Very	4.2	2.1	21.2	4.2	4.2	8.5	6.3	2.1
Extremely	0	2.15	0	6.35	2.1	0	2.1	2.1

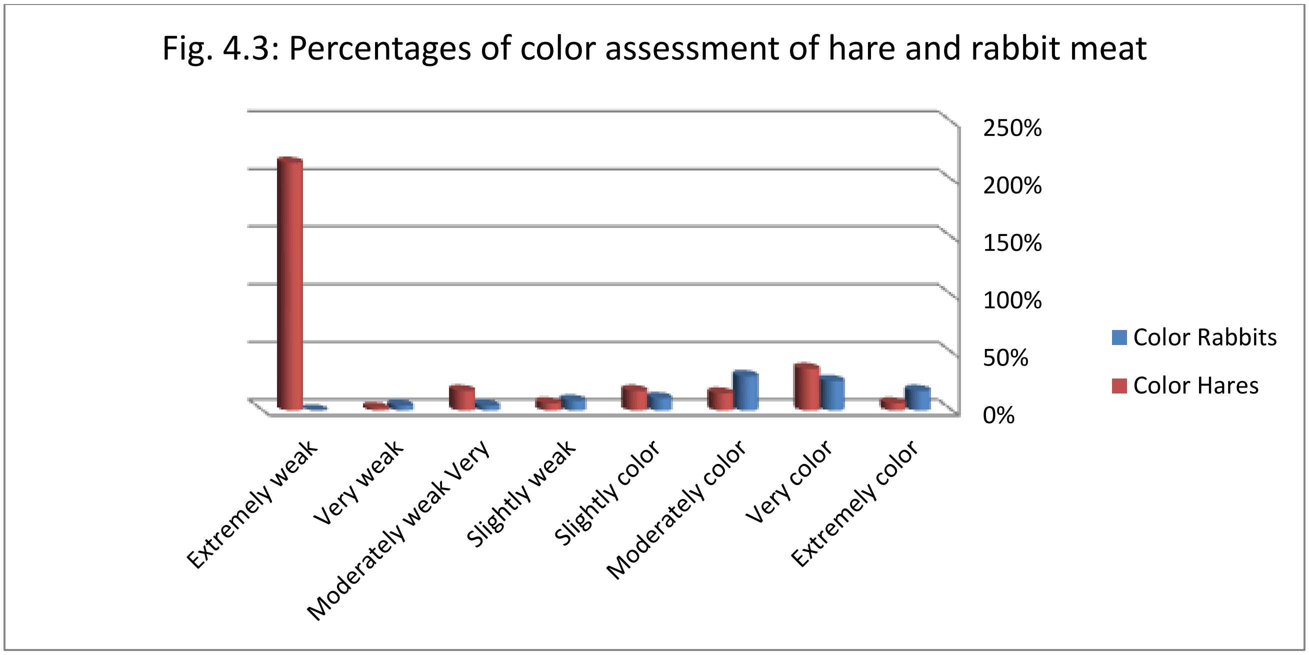


Fig. 4.3: Percentages of color assessment of hare and rabbit meat
250%
200%
150%
100%
50%
0%
Color Rabbits
Color Hares
Extremely weak
Very weak
Moderately weak Very
Slightly weak
Slightly color
Moderately color
Very color
Extremely color

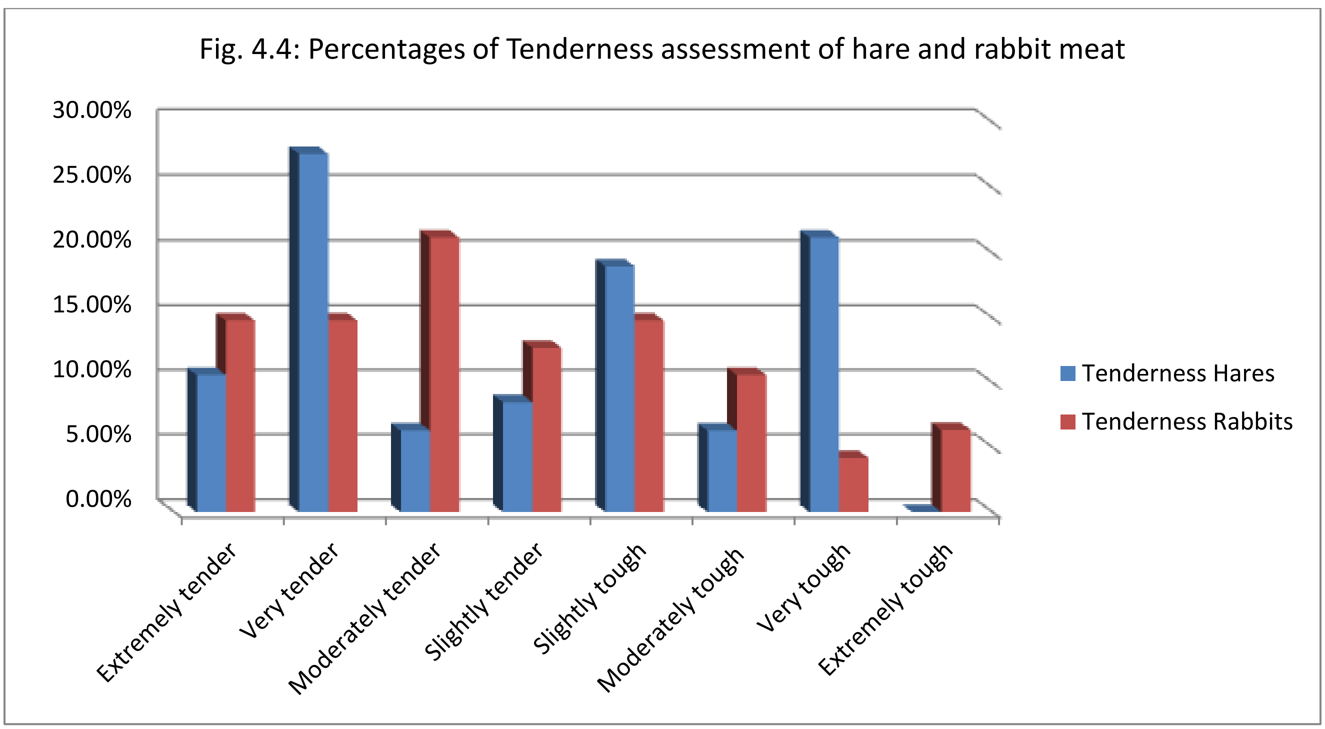


Fig. 4.4: Percentages of Tenderness assessment of hare and rabbit meat
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Tenderness Hares
Tenderness Rabbits
Extremely tender
Very tender
Moderately tender
Slightly tender
Slightly tough
Moderately tough
Very tough
Extremely tough

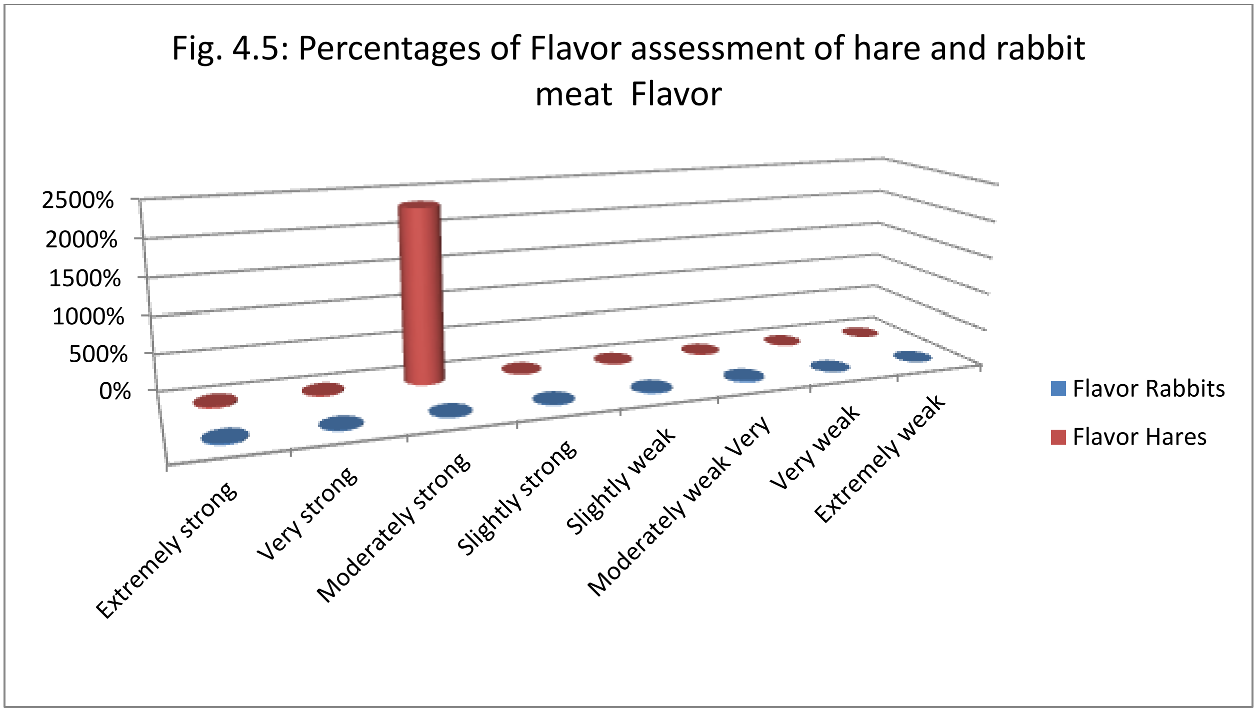


Fig. 4.5: Percentages of Flavor assessment of hare and rabbit meat Flavor
2500%
2000%
1500%
1000%
500%
0%
Extremely strong
Very strong
Moderately strong
Slightly strong
Slightly weak
Moderately weak Very
Very weak
Extremely weak
Flavor Rabbits
Flavor Hares

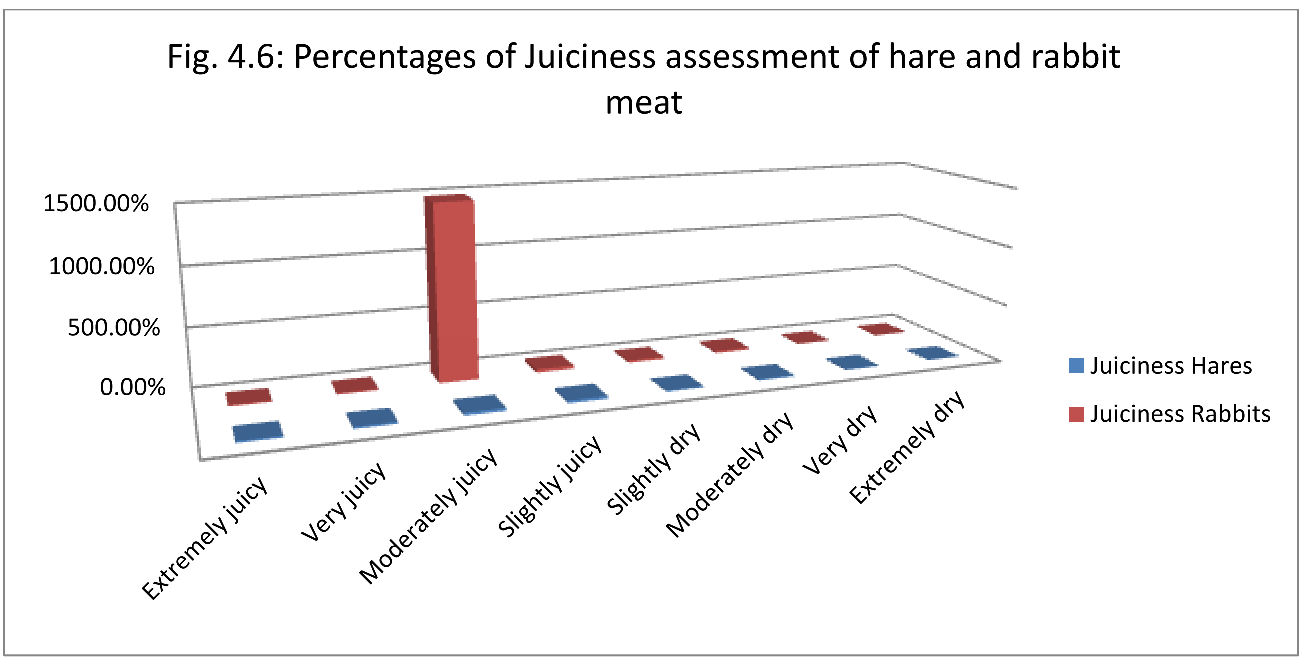


Fig. 4.6: Percentages of Juiciness assessment of hare and rabbit meat
1500.00%
1000.00%
500.00%
0.00%
Extremely juicy
Very juicy
Moderately juicy
Slightly juicy
Slightly dry
Moderately dry
Very dry
Extremely dry
Juiciness Hares
Juiciness Rabbits

CHAPTER FIVE

5. Discussion

5.1. Morphometrics:

The results that tail length of the hares from Al Managel area was longer than those hares from Abu Delig area is attributed to environmental factors such as the type of soil, abundance, quality of vegetation caver, temperature and climate, this agreed with Yom-Tov,Geffen (2011) and Fatima (2016) . In fact, morphological variation may determine individual performance and may be driven by ecological and behavioural adaptations (Garland and Losos, 1994; Harris and Steudel,1997). Cheylan, (1991) observed the *Lepus corsicanus* (Italian hare) is smaller in all external measurements and weight than the *Lepus europaeus* (European brown) hare. In general, *L. corsicanus* seems to be slenderer, with ear and hind foot longer than in *L. europaeus*. Since the historical and present distribution of *L. corsicanus* indicates it is an Italian endemism, body size should be an adaptation to the Mediterranean bio-climate. Size of ear and foot could be an adaptation for better thermoregulation in the warmer environment, as postulated by Allen's rule. Moreover there is a differences according to sex for total length, suggesting sexual dimorphism. This is in line with Gosler et al., (1995); Grant and Grant (1995); Yom-Tov , (2003); Yom-Tov et al .,(2003) Ozgul et al., (2009), and Mohamed (2016) who found the geographical variation in body size of animals is a common phenomenon , and has been related to many factors among which are predation , ambient temperature, fluctuations in various climatic phenomenon including climate change interspecific competition and food availability.

Many studies (Robinson and Dippenaar, 1987; Cervantes and Lorenzo, 1997) did not find sexual dimorphism in the genus *Lepus*. Riga et.al (2001) did not show sexual dimorphism although the body measurements he recorded differed among groups in different geographic area, and this more or less agree with my findings.

5.2. Craniometrics:

All skull measurements of hares based on geographic location are similar except (TBL), this agree with Mohamed (2016).. Therefore only TBL is useful for determining skull variations influenced by environment in different geographic locations which agreed with Mohamed (2016) and Riga et,al. (2001). Skulls were different between species and breed and between individuals of same breed and sex (Koing and Liebich, 2004)under conditions of food availability, either caused by human activity or higher primary productivity in latitudes (Yom-Tov and Geffen, 2011, McNab ,2010 and Hall, 1990),

5.2.1. Based on sex:

Differences of Skull measure ments (LCTRL ، MH ، UCTRL ، FlW and ML ANW ، TBL ، TL and WFT) between females and males is an appropriate measure for determining sexual dimoprphism.

As far as body measurements are concerned, only the tail length is useful for determining sexual dimorphism. This finding agreed with Mohamed (2016). It is concluded that hares from the three regions are likely conspecific but are affected by environmental factors and food availability. This is termed the "resource rule", especially during the growth period. This explains the difference between females and males because females get more food than males and the Quantity and quality of nutrition during this period affects growth rates and final body size, these effects on skeleton size carry over into adulthood (Read and Gaskin,1990; Ulijaszek et al., 1998 ; Ohlsson and Smith,2001; Searcy et al., 2004 ; Ho et al.,2010). This contrast what was found in in the island of Vir and in continental north-west Croatia, where no variations in craniometric, based on sex, is apparent although significant variations among geographical regions are evident as well as life history strategies and evolutionary change Yom-Tov,Geffen (2011). AS for the evaluation of the sensory characteristics of hare meat compared with domestic rabbit meat , this difference in juiciness is explained that the type of food eaten by the captive rabbit is always the right amount necessary for growth and productivity, whereas, wild rabbits muscles are larger for running and may sometimes suffer from inadequate food and water throughout the year.

CONCLUSIONS

Morphological measurements in this study showed that TBL differs with geographic location. ANW, ML, LCTRL, TBL, TL, and FIW are larger in females than males, indicating sexual dimorphism in hares. This is extended to total length and tail length which are longer for females. Domestic rabbit meat is juicier compared to the meat of wild hares.

RECOMMENDATIONS

1. There is a need for basic information on the quality and quantity of food in habitats of wild animals to assess variations in morphological and body measurements relative to food resources available.
2. Researcher and the wildlife department should cooperate in the conservation of the natural habitat of hares.
3. Encourage the breeding of wild hares to increase game meat for local consumption.
4. More studies are needed for hares fill the gaps of knowledge .

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