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قسم الاحياء

Comparative study of Some animals Protein in term of nutritional Value and Healthy benefits

By

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A research project submitted for the requirements of the Bachelor degree of Biology (499 Bio)

Under the supervision of:

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This research project has been approved and accepted in partial fulfillment of requirement for bachelor's degree in Biology Science

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بسم الله الرحمن الرحيم

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ACKNOWLEDGMENT

All praise and thanks are due to **Allah**, the Most Merciful and Compassionate, whose countless blessings, guidance, and grace have been the source of strength and perseverance throughout this journey. Without His divine assistance, this achievement would not have been possible.

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May Allah reward **everyone** who contributed to this success, and may this effort serve as a testament to the power of resilience and a step forward in the pursuit of knowledge and growth.

ABSTRACT

Proteins are essential macromolecules that support vital physiological processes such as tissue repair, immune defense, and metabolism. This study aims to evaluate and compare the nutritional profiles and health benefits of three animal protein sources: insects, beef, and camel meat. Samples of camel meat, beef, and insect larvae were collected from markets in Riyadh and analyzed using Lowry's method for protein quantification. Using spectrophotometry and refractometry, the study quantified protein content and assessed nutritional quality. Results revealed that beef has the highest protein content (105 mg/ml), followed by insects (63.2 mg/ ml) and camel meat (24.4 mg/ml). In terms of the Index of Nutritional Quality (INQ), beef scored the highest (13.235),. Insects, despite slightly lower INQ (8.165), Camel meat, while lower in protein concentration (INQ 3.155) .

This study concludes that while beef remains the most nutritionally robust protein source, insects offer a viable, eco-friendly alternative for future food systems. Camel meat serves as a culturally significant and health-conscious choice, particularly in arid regions. These findings highlight the need for further research on optimizing production and ensuring the safety of these diverse protein sources to address. It recommends further research into alternative protein sources, such as insects, to enhance food security. Additionally, balanced consumption of diverse protein sources is encouraged to optimize health outcomes and contribute to sustainable dietary practices.

الخلاصة

البروتينات هي جزيئات كبيرة ضرورية تدعم العمليات الفسيولوجية الحيوية مثل إصلاح الأنسجة، والدفاع المناعي، والتمثيل الغذائي. تهدف هذه الدراسة إلى تقييم ومقارنة الخصائص الغذائية والفوائد الصحية لثلاثة مصادر للبروتين الحيواني: الحشرات، ولحم البقر، ولحم الإبل. تم جمع عينات من لحم الإبل ولحم البقر ويرقات الحشرات من الأسواق في الرياض، تم تحديد كميه البروتين باستخدام أجهزة قياس الطيف والانكسار الضوئي وتم تحليلها باستخدام طريقه Lowry.

قامت الدراسة بقياس محتوى البروتين وتقييم الجودة الغذائية، كشفت النتائج أن لحم البقر يحتوي على أعلى نسبة بروتين (105 ملغ/مل)، يليه الحشرات (63.2 ملغ/مل)، ثم لحم الإبل (24.4 ملغ/مل). فيما يتعلق بمؤشر الجودة الغذائية - Index of Nutritional Quality) (INQ، سجل لحم البقر أعلى درجة (13.235)، تلاه الحشرات بدرجة أقل قليلاً (8.165). أما لحم الإبل، فقد كان أقل من حيث تركيز البروتين (INQ 3.155) .

تخلص هذه الدراسة إلى أن لحم البقر يظل المصدر الأكثر تغذية بين البروتينات، بينما تقدم الحشرات بديلاً صديقًا للبيئة وواعدًا لأنظمة الغذاء المستقبلية. يُعد لحم الإبل خيارًا ذا أهمية ثقافية وصحيًا، خاصة في المناطق الجافة. تُبرز هذه النتائج الحاجة إلى إجراء مزيد من الأبحاث لتحسين الإنتاج وضمان سلامة هذه المصادر المتنوعة من البروتينات لتلبية احتياجات الأمن الغذائي. كما توصي الدراسة بإجراء أبحاث إضافية حول مصادر البروتين البديلة، مثل الحشرات، لتعزيز الأمن الغذائي. بالإضافة إلى ذلك، تشجع على استهلاك متوازن لمصادر البروتين المتنوعة لتحسين النتائج الصحية والمساهمة في ممارسات غذائية مستدامة.

List of Abbreviation

Abbreviation	Meaning
LDL	Low-Density Lipoprotein
S.V.	Scientific Version
EFSA	European Food Safety Authority
NFE	Nitrogen-Free Extract
PUFA	Polyunsaturated Fatty Acids
B12	Vitamin B12 (Cobalamin)
IgE	Immunoglobulin E
DNA	Deoxyribonucleic Acid
HACCP	Hazard Analysis and Critical Control Points
E. coli	Escherichia coli
L-Carnitine	A compound naturally produced in the body for energy production
B3	Vitamin B3 (Niacin)
EU	European Union
mg	Milligram
g	Gram
et al	and others
UK	United Kingdom
WWF	World Wildlife Fund
INQ	Index of Nutritional Quality
OD	Optical Density

CHAPTER ONE
INTRODUCTION

Introduction

Proteins are indispensable macromolecules vital for sustaining life and promoting health. They serve as key regulators in biological processes like metabolism, cellular regeneration, and growth, while maintaining the immune system. Proteins are hydrolyzed into amino acids, absorbed, and transported to tissues for vital functions such as enzyme production and tissue repair (Coşkun & Dağ, 2022; Wu et al., 2018). Approximately 20% of the human body is composed of proteins, highlighting their importance (Eskici, 2020). They are essential for physiological processes such as cellular growth, tissue repair, enzymatic activity, immune defense, and hormone regulation. The nutritional value of a protein depends on its source, amino acid composition, digestibility, and bioavailability (Wu et al., 2018; Coşkun & Dağ, 2022).

Dietary proteins are categorized as animal-based or plant-based. Animal proteins, found in meat, fish, eggs, and dairy, provide all essential amino acids, ensuring superior digestibility and bioavailability. In contrast, plant proteins, like those in legumes and grains, may lack essential amino acids but can be complemented for a complete amino acid profile (Wu et al., 2018; Coşkun & Dağ, 2022).

Beyond structural roles, proteins promote muscle growth, bone density, and immune health, aiding antibody production (Eskici, 2020). Studies show soy proteins reduce low density lipoprotein (LDL) cholesterol, lowering risks of cardiovascular diseases, while casein proteins bind minerals to reduce chronic disease risks (Pulluk & Oğan, 2021). Proteins also aid post-exercise recovery by repairing muscle fibers (Eskici, 2020).

As the global population grows, the world's natural and finite resources are becoming increasingly strained. The United Nations estimates that the world population is projected to reach 8.5 billion by 2030 and 9.7 billion by 2050 (United Nations, 2019). To provide enough food globally in line with a growing population, socio-economic changes, and measures to address hunger, food insecurity, and malnutrition, efficient and sustainable food production systems are required (FAO, 2018).

Humans require a range of essential nutrients, including proteins, carbohydrates, fats, vitamins, minerals, and water, to support life and health. Of particular importance is protein, consisting of animal and plant-based sources. However, the average citizen in the United Kingdom (UK) and Europe consumes unsustainable levels of animal protein (Development of a Roadmap to Scale up Insect Protein Production, Ffoulkes et al., 2021).

The World Wide Fund for Nature (WWF) recognizes that while animal protein will remain an important part of diets, the demand for meat and fish-based products will rise alongside population growth. This increase also elevates the demand for protein-rich feed ingredients, emphasizing the need for sustainable animal protein production (Ffoulkes et al., 2021).

To address global challenges like climate change and resource scarcity, alternative protein sources—such as algae, insects, and cultured meat—are being explored for sustainability (Van der Spiegel et al., 2012; Uçar et al., 2023). These innovations aim to ensure nutritional adequacy while reducing environmental impacts.

In conclusion, proteins are essential for health, chronic disease prevention, and sustainable nutrition. Ongoing research highlights their diverse roles and their potential to address global food security challenges (Wu et al., 2018; Baştürk et al., 2021).

Research Objective:

General Objective:

To assess the nutritional composition and health benefits of various animal protein sources, including insects, beef, and camel meat .

Specific Objectives:

- To extract and prepare concentrated protein samples from selected animal source.
- To conduct a comparative analysis of nutritional profiles of insect,beef, and camel protein.
- To identify the protein source with the highest nutritional value and potential health benefits.

CHAPTER TWO

LITERATURE REVIEW

LITERATURE REVIEW

2.1 Animal-based proteins

Proteins derived from animals are more high-priced, but animal derived proteins have almost all required amino acids and their pattern is also same as the requirements of the human body. Proteins have their traditional important sources such as animal-derived proteins including milk, meat, poultry. (Tahergorabi, Hosseini, S.V., 2017).

There are some alternative protein sources like proteins derived from insects derived proteins emerging to meet the high demand for dietary proteins for the growing population. Together traditional and alternative sources can significantly enhance the production of healthy protein and positively impact global food security. (Tahergorabi 2017; Franca, sedlar, 2021)

Meat, the key element of a balanced diet, is the animals' palatable skeletal portion. Throughout history, it has served as a major source of animal-derived proteins. Meat consumption yields significantly important nutritious proteins, fatty acids, fats, vitamins, and some other important biological proteins that have different important functions in humans. (Boateng 2020; Swart 2013)

Eating insects has rich signs in history and has gained more attention in the current scenario of burgeoning demand for nutrition utilizing limited natural resources. And has its footprints in the tropical regions of the world where they have several varieties. (Imanthiu 2020; Garofalo 2019)

Entomophagy (insect eating) has its benefits as insects have a balanced nutrition and they are rich in proteins, fats (monosaturated and polyunsaturated), and vitamins. Entomophagy has a lot of environmental benefits like reduced greenhouse gas emissions and other measures for the prevention of climate change. Insect rearing needs less land and other resources like water in contrast with other livestock rearing for nutritious food production. It can be done on organic waste materials to produce valuable nutrition for global food security. (Liceaga, 2022)

Proteins mainly contain 45-55% carbon, 6-8% hydrogen, 20-25% oxygen, 15-17% nitrogen, 0-3% sulfur, 0-0.8% phosphorus and in some cases may also contain iron and copper. They are biopolymer substances. They are formed by combining amino acids in different numbers and sequences. They are compounds with large molecular weights, amphoteric character and long chains. Proteins have unique biological properties and three-dimensional structures. The uniqueness of proteins is provided by the number, type and sequence of amino acids that make up the polymer chain. (Demirci, 2012)

2.2 Benefits of animal proteins

1- Essential for providing high-quality amino acids critical for muscle growth, immune function, cellular repair.

2- Rich source of bioavailable nutrients like iron, zinc, and B vitamins, which support overall health, energy production, and immune strength.

3- Important during growth phases, physical recovery, and periods of increased physiological demand.

4- Its digestibility and nutrient density make it a valuable component of a balanced diet. (Elmadfa, Meyer, 2017)

5- Intake of animal-based proteins during late pregnancy is believed to have a vital role in infants born with normal body weights. (Hoffman JR, Falvo MJ, 2004)

6- Play major roles in the renewal and repair of structures and organs such as bones, muscles, skin and hair.

7- Maintaining the immune system and vital functions.

8- Play protective roles against life-threatening diseases such as diabetes, obesity and heart disease. (Shang, 2018)

2.2.1 Insect protein:

Consumption of sufficient amounts of dietary protein is fundamental to human growth and overall health. Dietary protein plays an important role in improving diet quality, promoting healthy aging, supporting body weight management, improving body composition, regulating appetite, and maintaining/increasing skeletal muscle mass in certain populations Therefore, protein consumption plays an important role in managing current public health issues such as obesity and age-related muscle loss. (Tyler A,2017)

With an increase in the global population, alternative protein sources, in addition to the conventional animal and plant-based proteins, will be required to meet global demands for dietary protein and ensure global food security. Insects have been proposed as an alternative protein-dense food source that may be produced on a more viable and sustainable commercial scale. (Tyler A,2017).

Interest in insects as food and feed has largely centeredon their potential role as nutrient concentrators, associated with their ability to grow on relatively low-quality diets and assimilate high-quality protein and a range of other essential nutrients. The nutritional value of insects varies depending on the species and their diet and development stage. In general, they are a good source of energy, high-quality protein, as well as a range of readily available vitamins and Minerals. (Hawkey, 2021) the protein content of edible insects is relatively high, ranging from approximately 40% for insects belonging to the order Isoptera (termites) and Coleoptera (beetles) to approximately 60% for insects from the order Blattodea (cockroaches) and Orthoptera (crickets, grasshoppers, locusts) (Tyler A, 2017).

Edible insects as an alternative protein source for human food and animal feed are interesting in terms of low greenhouse gas emissions, high feed conversion efficiency, low land use, and their ability to transform low value organic side streams into high value protein products (van Huis, 2016).

More than 2,000 insect species are considered edible, with most of these originating in tropical countries. EFSA (2015) list the following species as those which are reported to have the 'biggest potential' to be used as food and feed in the EU, although it is unclear what factors contributed to making this assessment:

- *Musca domestica*: Common housefly
- *Hermetia illucens*: Black soldier fly
- *Tenebrio molitor*: Mealworm
- *Zophobas atratus*: Giant mealworm
- *Alphitobus diaperinus*: Lesser mealworm
- *Galleria mellonella*: Greater wax moth
- *Achroia grisella:* Lesser wax moth
- *Bombyx mori*: Silkworm
- *Acheta domesticus*: House cricket
- *Gryllodes sigillatus*: Banded cricket
- *Locusta migratora migratorioides*: African migratory locust

• *Schistocerca Americana*: American grasshopper

(Ffoulkes, 2021).

The insects can be used as whole insects, processed into powders or pastes; or protein isolate, fat/oil or chitin can also be extracted from the insect. To be used as ingredients in food or feed are typically prepared into powders or pastes by milling either after drying, or when frozen. Extraction technologies using water or steam can be used to separate large insoluble chitin particles from ground insects, with organic solvent extraction used to separate fats and oils from the protein. Before distribution of whole insects (for food or feed), these are typically blanched, chilled or dried in order to extend shelf life and reduce the microbial load (Ffoulkes, 2021).

2.2.1.1 Nutritional value of insects

Insects are nutritious foods because of their high (20 to 76% of dry matter) and valuable protein content, but it is highly variable because of the wide variety of species, and its value also differs depending on the metamorphic state of the insect. Insect proteins contain measurable amount of essential amino acids such as tryptophan, lysine, and histidine. Insect proteins are highly digestible (77–98%), although the exoskeleton – due to the presence of chitin – is lowering it (M. MÉZES,2018).

Chitin is largely believed to be indigestible by humans, although chitinase has been found in human gastric juices. Otherwise, chitin acts like a dietetic fibre, and this could imply a high fibre content in edible insects. Insects also contain trace elements (copper, iron, manganese, selenium, and zinc) and vitamins. Preparation and processing methods (e.g. drying, boiling, or frying) applied before consumption will also influence the nutritional composition.(M. MÉZES,2018).

It is difficult to generalise the nutritional value of insects, because it varies with species, gender, developmental stage, diet, the environment (temperature, humidity and photoperiod) and even with the analytical methods use. Many species are rich in protein and fat, essential amino acids, and fatty acids as well as vitamins and minerals (van Huis, 2016).

But some general insights include:

•Protein Content: Insects are rich in protein, with levels typically ranging from 30% to 80% of their dry weight, depending on the species. Common insect species used for protein production include crickets, mealworms, and grasshoppers. For instance, crickets contain approximately 60-70% protein by dry weight.

• Amino Acids: Insects provide a complete protein source, meaning they contain all nine essential amino acids required for human health. This makes insect protein highly valuable for both human and animal diets.

• Fats: Insects also provide healthy fats, including essential fatty acids like omega-3 and omega-6. Mealworms, for example, are rich in monounsaturated and polyunsaturated fats, which can be beneficial for heart health.

• Micronutrients: Insects are packed with essential vitamins and minerals, including iron, zinc, magnesium, and B vitamins (such as B12, riboflavin, and niacin). These micronutrients are crucial for metabolic function, immune health, and overall well-being.

• Fiber: Many insect species also hold chitin, a fibrous substance found in their exoskeletons. While chitin is not digestible by humans, it can act as a prebiotic, supporting gut health by stimulating beneficial gut bacteria (Zhou.Y, 2022). see Table 2.1

Table 2.1 Proximate nutrient composition of edible insects.

Insect	Developmental stage	Protein	Fat	Fibre	NFE *	Ash
Blattodea (including infra order Isoptera)						
Edible cockroaches and termites		46.3	31.3	5.2	13.7	4.4
Macrotermes bellicosus	A	40.7	44.8	5.3	2.2	5.0
Macrotermes nigeriensis	A	37.5	48.0	5.0	2.1	3.2
Odototermes sp.	A	33.7	50.9	6.3	6.1	3.0
Syntermes sp. soldier	A	64.7	3.1	23.0	2.5	4.2
Coleoptera						
Edible beetles		40.7	33.4	10.7	13.2	5.1
Allomyrina dichotoma	L	54.2	20.2	4.0	17.7	3.9
Oryctes rhinoceros	L	52.0	10.8	17.9	2.0	11.8
Protaetia brevitarsis	L	44.2	15.4	11.1	22.5	6.9
Tenebrio molitor	L	53.2	34.5	6.3	1.9	4.0
Tenebrio molitor	P	51.0	32.0	12.0	–	–
Zophobas morio	L	46.0	35.0	6.0	–	–
Diptera						
Edible flies		49.5	22.8	13.6	6.0	10.3
Caliphora vomitoria	A	64.9	0.7	16.6	12.2	5.6
Hermetia illucens	Pre P	44.3	31.9	5.1	3.4	8.7
Hermetia illuscens	L	39.0	32.6	12.4	–	14.6
Hemiptera						
Edible bugs		48.3	30.3	12.4	6.1	5.0
Aspongopus nepalensis	A	10.6	38.4	33.5	15.3	2.2
Hymenoptera						
Edible ants, bees, wasps		46.5	25.1	5.7	20.3	3.5

Oecophylla smaragdina	**A**	**55.3**	**15.0**	**19.8**	**7.3**	**2.6**
			Lepidoptera			
Edible moth		**45.4**	**27.7**	**6.6**	**18.8**	**4.5**
Cirina butyrospermi	**L**	**62.7**	**14.5**	**5.0**	**12.6**	**5.1**
Odonata						
Edible dragonfly, damselfly		**55.2**	**19.8**	**11.8**	**4.6**	**8.5**
Orthoptera						
Edible grasshoppers, crickets, locusts		**61.3**	**13.4**	**9.6**	**13.0**	**3.9**
Acheta domesticus	**A**	**62.6**	**12.2**	**8.0**	**12.3**	**5.0**
Brachytrupes sp.	**A**	**65.4**	**11.8**	**13.3**	**2.5**	**4.9**
Brachytrupes orientalis	**A**	**65.7**	**6.3**	**8.8**	**15.2**	**4.3**
Chondacris rosea	**A**	**68.9**	**7.9**	**12.4**	**6.7**	**4.2**
Gryllus assimilis	**A**	**56.0**	**32.0**	**7.0**	–	_
Gryllus bimaculatus	**A**	**58.3**	**11.9**	**9.5**	**10.6**	**9.7**
Ruspolia nitidula	**A**	**40.8**	**46.3**	**5.9**	**3.7**	**3.3**
Schistocerca piceifrons piceifrons	**A**	**80.3**	**6.2**	**12.6**	–	**3.4**
Teleogryllus emma	**A**	**55.7**	**25.1**	**10.4**	**0.7**	**8.2**

(Rochow Meyer,2021)

Table 2.2: Amino acid composition of insects

Scientific Name	Ile	Leu	Lys	Met	Cys	Phe	Tyr	Thr	Trp	Val	Arg	His	Ala	Asp	Glu	Gly	Pro	Ser
Antheraea pernyi	79.5[a]	32.4[a]	45.4[a]	14.7[a]	1.5[a]	81[a]	20.6[a]	46.4[a]	40.5[a]	66.3[a]	41.2[a]	29.4[a]	62.6[a]	64.1[a]	127.4[a]	44.2[a]	122.2[a]	46.4[a]
Bombyx mori	57[a]	83[a]	75[a]	46[a]	14[a]	51[a]	54[a]	54[a]	6[a]	56[a]	68[a]	25[a]	55[a]	109[a]	149[a]	46[a]	40[a]	47[a]
Gryllodes sigillatus	25.6	57.8	38.4	15.9	11.1	22.0	31.8	36.8	NA	47.0	46.6	17.2	58.0	72.8	106.6	40.7	54.2	40.4
Schistocerca gregaria	28.2	77.7	35.1	8.2	3.6	18.7	33.1	35.5	NA	56.6	39.8	20.6	88.8	66.1	107.5	49.4	67.1	33.7
Hermetia illucens	7.62[b]	12.1[b]	11.9[b]	3.37[b]	1.02[b]	7.56[b]	12.1[b]	6.82[b]	3.00[b]	12.9[b]	12.3[b]	5.94[b]	12.2[b]	16.5[b]	19.7[b]	9.14[b]	10.2[b]	7.02[b]
Chilecomadia moorei	6.51[b]	10.1[b]	8.72[b]	2.49[b]	0.87[b]	5.47[b]	7.95[b]	5.74[b]	1.56[b]	9.71[b]	11.7[b]	4.08[b]	8.67[b]	12.9[b]	16.4[b]	6.53[b]	9.52[b]	7.88[b]
Blatta lateralis	7.73[b]	12[b]	12.8[b]	3.35[b]	1.44[b]	7.67[b]	14.3[b]	7.89[b]	1.66[b]	12.3[b]	14[b]	5.49[b]	16.7[b]	15.1[b]	22.6[b]	12.4[b]	10.6[b]	8.38[b]
Musca domestica	8.1[b]	12.4[b]	12.6[b]	5.84[b]	1.4[b]	7.91[b]	9.26[b]	7.54[b]	2.4[b]	11[b]	12.1[b]	5.71[b]	11.7[b]	16.3[b]	21.1[b]	8.43[b]	8.36[b]	6.97[b]
Zophobas morio	9.3[b]	19.1[b]	10.3[b]	2.1[b]	1.5[b]	6.8[b]	13.7[b]	7.8[b]	1.8[b]	10.3[b]	9.6[b]	6.0[b]	14.3[b]	15.8[b]	24.2[b]	9.5[b]	10.8[b]	9.2[b]
Tenebrio molitor	8.6[b]	14.3[b]	11.2[b]	2.6[b]	1.5[b]	7.5[b]	14.3[b]	6.4[b]	1.7[b]	12.2[b]	10.3[b]	6.5[b]	13.7[b]	16.2[b]	22.8[b]	9.9[b]	12.1[b]	9.1[b]
Galleria mellonella	6.3[b]	12.4[b]	7.9[b]	2.2[b]	1.1[b]	5.3[b]	8.8[b]	5.9[b]	1.2[b]	6.8[b]	7.1[b]	3.3[b]	9.4[b]	13.4[b]	19.5[b]	7.4[b]	9.5[b]	10.5[b]
Acheta domesticus	9.4[b]	20.5[b]	11.0[b]	3.0[b]	1.7[b]	6.5[b]	10.0[b]	7.4[b]	1.3[b]	10.7[b]	12.5[b]	4.8[b]	18.0[b]	17.2[b]	21.5[b]	10.4[b]	11.5[b]	10.2[b]
Gryllus bimaculatus	9.2[b]	16.5[b]	11.4[b]	3.5[b]	1.6[b]	7.4[b]	11.7[b]	8.1[b]	2.2[b]	13.6[b]	11.4[b]	5.2[b]	19.3[b]	19.7[b]	24.4[b]	12.4[b]	12.5[b]	10.5[b]
Gonimbrasia belina	13.0[c]	18.3[c]	25.6[c]	4.1[c]	1.1[c]	13.5[c]	22.3[c]	18.4[c]	4.8[c]	19.1[c]	45.7[c]	18.4[c]	23.6[c]	31.3[c]	43.5[c]	17.9[c]	18.6[c]	17.5[c]

Table 2.2: Amino acid composition of insects																		
Scientific Name	Ile	Leu	Lys	Met	Cys	Phe	Tyr	Thr	Trp	Val	Arg	His	Ala	Asp	Glu	Gly	Pro	Ser
Gynanisa maja	18.8 [c]	27.2 [c]	40.2 [c]	8.2 [c]	2.2 [c]	19.8 [c]	41.7 [c]	22.6 [c]	7.5 [c]	20.9 [c]	31.4 [c]	25.3 [c]	25.5 [c]	39.9 [c]	52.4 [c]	19.9 [c]	25.0 [c]	23.1 [c]
Ruspolia differens	26.1 [c]	26.7 [c]	57.4 [c]	4.3 [c]	0.7 [c]	26.1 [c]	25.3 [c]	28.6 [c]	0.3 [c]	16.4 [c]	49.8 [c]	44.1 [c]	26.6 [c]	49.0 [c]	84.3 [c]	26.0 [c]	19.0 [c]	25.9 [c]
Macrotermes falciger	18.9 [c]	31.6 [c]	37.2 [c]	8.2 [c]	1.3 [c]	19.7 [c]	34.4 [c]	19.5 [c]	3.5 [c]	21.7 [c]	30.1 [c]	26.5 [c]	27.4 [c]	37.3 [c]	46.8 [c]	18.9 [c]	19.3 [c]	20.8 [c]
Imbrasia belina	22.0 [c]	35.0 [c]	36.0 [c]	9.0 [c]	NA	25.0 [c]	36.0 [c]	27.0 [c]	7.0 [c]	NA	32.0 [c]	17.0 [c]	NA	NA	NA	NA	NA	NA
Apis mellifera	16.0 [c]	25.0 [c]	19.0 [c]	NA	3.0 [c]	2.0 [c]	15.0 [c]	16.0 [c]	NA	17.0 [c]	16.0 [c]	7.0 [c]	16.0 [c]	26.0 [c]	50.0 [c]	14.0 [c]	NA	14.0 [c]
Rhynchophorus ferrugineus	8 [c]	12 [c]	11 [c]	2 [c]	1 [c]	7 [c]	21 [c]	8 [c]	1 [c]	10 [c]	10 [c]	4 [c]	11 [c]	16 [c]	25 [c]	9 [c]	10 [c]	9 [c]

(Zhou, 2022)

2.2.1.2 Health Benefits of Insect Proteins

Insect proteins offer various health benefits for human consumers due to their unique nutritional profile:

1. High-Quality Protein Source: Insect proteins are highly bioavailable, meaning they are easily digested and absorbed by the body. They provide all the essential amino acids needed for muscle repair, immune function, and overall tissue maintenance. (Zhou.Y, 2022)

2. Improved Muscle Mass and Recovery: Due to their complete amino acid profile and high protein content, insect proteins can be beneficial for building

and repairing muscle tissue, making them a good choice for athletes, bodybuilders, and those recovering from illness. (Aguilar Toalá, 2022)

3. Gut Health: The presence of chitin, a prebiotic fiber in many insects, can support gut health by promoting the growth of beneficial bacteria in the digestive tract. This may improve digestion and overall gut microbiome health. (Aguilar Toalá, 2022)

4. Reduced Risk of Nutrient Deficiencies: Insects are rich in key micronutrients, particularly iron and zinc, which are vital for preventing deficiencies that can lead to anemia, weakened immune systems, and poor wound healing. Iron from insects is highly bioavailable, meaning it is absorbed more efficiently than from plant-based sources.

5. Sustainability and Safety: Insects are a highly sustainable food source that requires minimal land, water, and feed to produce, contributing to a more sustainable food system. Furthermore, they are generally safe to eat when farmed under controlled conditions and have been used as food in various cultures for centuries (Liceaga, A, 2022).

2.2.1.3 Food safety

Some safe insects may be unhealthy if they contain allergens or are fed with plants originated from a polluted area. (M. MÉZES,2018).

2.2.1.3.1 Allergic reactions

Like most protein-containing foods, arthropods can induce IgE-mediated allergic reactions in sensitive humans. These allergens may cause eczema, dermatitis, rhinitis, conjunctivitis, congestion, angioedema, and bronchial asthma. While some people have a history of atopy (allergic hypersensitivity), it is also possible to develop allergic sensitivity through long-term exposure. (M. MÉZES,2018).

The majority of cases are inhalant or contactant in nature. Tropomyosins from cockroaches, mites, and shrimps have been reported to be allergenic. The findings suggest that people with seafood allergy also have allergic reactions in case of consuming edible insects. (M. MÉZES,2018).

The processing, such as boiling, has doubtful effect on destroying the allergenic components. For those people, who have no history of arthropod or insect allergen sensitivity, usually have no acquired sensitivity for allergic reactions, even if they eat and/or are exposed to insects through long-term exposure in sufficient quantities. (M. MÉZES,2018).

2.2.1.3.2 Microbial safety

Insects may have associated microorganisms that can influence their safety as food. The presence of pathogenic bacteria is influenced by the hygienic conditions of the substrate and the environment, namely rearing conditions. Both insects collected in nature or raised on farms may be infected with pathogenic microorganisms, such as bacteria (Staphylococcus, Bacillus, Campylobacter, Pseudomonas, Micrococcus, Acinetobacter, Proteus, Escherichia, Enterobacteriaceae, and other spore-forming bacteria), also virus, fungi, and protozoa. (M. MÉZES,2018).

Transmission of prions through edible insects has not been proven yet, only some ectoparasites, such as Hypoderma bovis and Oestrus ovis, were found as possible transmission factors. Furthermore, the risk of transmission of these bacteria could be mitigated through effective processing. (M. MÉZES,2018).

2.2.2 Beef Protein

Beef protein is a high-quality protein source containing a complete profile of essential amino acids necessary for building body tissues and supporting vital functions. It holds a prominent position among animal proteins due to its exceptional nutritional value and positive effects on health and physical performance (Joanna stadnik, 2024).

Beef protein is a versatile and nutritionally rich option that supports various bodily functions and enhances physical performance, particularly for athletes. It is a reliable dietary choice for individuals aiming to improve overall health or achieve athletic goals (Martina et al, 2022).

2.2.2.1 Nutritional Value of Beef Protein

Beef protein offers a comprehensive blend of essential amino acids, including leucine, which is critical for activating muscle protein synthesis. In addition to protein, beef contains several vital nutrients such as:

-Iron and Zinc: Essential for blood health and immune system functionality Beef is rich in zinc, an essential element for supporting the immune system, wound healing, and DNA synthesis. An 85-gram serving provides about 30% of the daily requirement for adults.

Heme Iron: The iron in beef is heme iron, which is absorbed by the body more efficiently compared to non-heme iron found in plants. This makes beef effective in preventing iron deficiency anemia (Kimball, 2024).

- Carnosine: Beef contains high levels of carnosine, a compound that helps reduce inflammation and mitigates damage caused by glycation, a process associated with aging and chronic diseases (Michael Joseph, 2024).

- Healthy Fats: Beef contains healthy fats like omega-3 fatty acids, which contribute to improved heart health, support brain functions, and reduce inflammation (Kimball, 2024).

- Vitamins: Beef is an excellent source of B vitamins, such as B12 and B6, which support nerve functions and energy production. An 85-gram serving provides about 82% of the daily requirement for vitamin B12 Crucial for energy production and nervous system health (Michael Joseph, 2024).

Table 2.3 Essential amino acid composition in beef meat (mg/100g).

	Camel	Beef	Chicken
Essential Amino Acids			
Lysine	**8.45**	**9.12**	**8.96**
Threonine	**4.4**	**4.64**	**4.16**
Valine	**5.16**	**5.28**	**4.8**
Methionine	**2.41**	**2.72**	**2.40**
Isoleucine	**5.23**	**5.12**	**4.64**
Leucine	**8.41**	**8.00**	**7.52**
Phenylalanine	**4.24**	**4.48**	**4.48**
Histidine	**4.33**	**3.20**	**3.04**
Non-Essential Amino Acids			
Arginine	**7.38**	**6.72**	**6.24**
Aspartic Acid	**9.09**	**9.60**	**9.12**
Serine	**3.63**	**4.48**	**4.00**
Glutamic Acid	**16.91**	**17.28**	**16.48**
Proline	**5.39**	**5.12**	**4.16**
Glycine	**5.95**	**5.60**	**4.82**
Tyrosine	**3.23**	**3.84**	**3.52**
Alanine	**6.25**	**6.40**	**5.76**
Cystine	**-**	**1.28**	**1.28**
Tryptophan	**0.60**	**1.28**	**1.12**

(Waqas, 2021)

2.2.2.2 Effects on Physical Performance

Studies indicate that consuming beef protein supplements in combination with exercise enhances body composition and increases muscle mass. A double-blind study revealed that post-workout consumption of beef protein led to a 5.7% increase in muscle mass compared to a 4.7% increase with whey protein (Valenzuela et al ,2019).

2.2.2.3 Health Benefits

1. Moderate beef consumption has been shown to support cognitive development in children due to its iron and zinc content (Kimball, 2024)

2. It also promotes muscle and bone health in adults (Valenzuela et al,2019).

3. Enhances energy levels and overall vitality (Michael Joseph, 2024)

2.2.2.4 Food safety

Food safety concerns related to beef protein production and consumption have been a focal point in public health and agricultural practices. Here are the key considerations based on recent studies:

2.2.2.4.1 Microbial Contamination Risks

Beef is highly susceptible to contamination by pathogens such as *E. coli*, Salmonella, and Listeria. These can arise during slaughter, processing, or improper handling. Addressing hygiene in processing facilities and implementing Hazard Analysis and Critical Control Point (HACCP) systems are vital (Hadi & Brightwell, 2021)).

2.2.2.4.2 Antibiotic Use and Resistance

The overuse of antibiotics in cattle farming has raised concerns about antimicrobial resistance, which could lead to ineffective treatments for infections in humans. Alternative practices, such as vaccination and improved farm management, are recommended to mitigate this issue (Makkar et al., 2018).

2.2.2.4.3 Chemical Residues

Pesticides, heavy metals, and veterinary drugs in feed can accumulate in beef, posing health risks. Regulatory frameworks, including regular monitoring and setting maximum residue limits, are necessary to ensure consumer safety (Leroy et al., 2022).

2.2.2.4.4 Sustainability and Ethical Concerns

The environmental impact of beef production, including greenhouse gas emissions and resource use, indirectly influences food safety through ecosystem degradation. Sustainable practices, such as improved feed efficiency and reducing methane emissions, are critical (Huang et al., 2018).

2.2.3 Camel Protein

Camel meat is a highly nutritious protein source, widely consumed in arid regions like the Middle East and North Africa. Its unique nutritional profile, including low fat and cholesterol levels, makes it an ideal option for health-conscious individuals and a competitive alternative to traditional red meats such as beef and lamb (Joanna stadnik, 2024).

Camel meat is a nutritious, sustainable, and health-conscious choice. Its rich protein content, low fat, and numerous health benefits make it a promising alternative to conventional red meats for both local and international markets (Joanna stadnik, 2024).

2.2.3.1 Nutritional Value of Camel Meat Protein

Camel meat is rich in high-quality protein and essential amino acids, comparable to other animal proteins. Notably, it contains:

- Low intramuscular fat: Around 1–2%, significantly less than beef (Djamal & Mohammed, 2022).

- High iron and zinc levels: Essential for oxygen transport and immune function (Baba et al., 2021).

- Polyunsaturated fatty acids (PUFAs): Beneficial for cardiovascular health (Isam T. Kadim,et al,2022).

- Low intramuscular fat: Camel meat contains about 1-2% fat, making it a lean protein source, significantly lower than beef, which typically contains 5-25% fat (Djamal & Mohammed, 2022).

- Rich in essential amino acids: The amino acid profile of camel meat supports muscle repair and growth, with lysine, leucine, and valine in high concentrations (Elgasim & Alkanhal, 1992).

- High iron content: Camel meat contains approximately 20-30 mg of iron per 100 g, which supports oxygen transport in the blood and prevents anemia (Baba et al., 2021).

- High zinc levels: With about 3-5 mg of zinc per 100 g, camel meat boosts immune function and aids in wound healing (Mohammed et al., 2016).

- Rich in polyunsaturated fatty acids (PUFAs): Camel meat contains omega-3 and omega-6 fatty acids, which are beneficial for cardiovascular health and reduce inflammation (Isam T. Kadim, et al,2022).

- Low cholesterol levels: Camel meat has lower cholesterol compared to beef and mutton, making it a heart-friendly protein choice (Abdelhadi et al., 2013).

- Hypoallergenic properties: Camel meat is less likely to trigger allergic reactions, making it suitable for individuals with allergies to common meats like beef or chicken (Kurtu, 2004).

- Rich in vitamins: Camel meat has vitamins B3 and B12, essential for energy metabolism and nerve function (Mohammed et al., 2016).

Table 2.4 Chemical composition of meat from distinct species.

Species	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Camel	**71.0**	**21.4**	**4.4**	**1.1**
Beef	**71.5**	**21.5**	**5.5**	**0.9**
Sheep	**68.9**	**21.0**	**8.5**	**1.2**
Goat	**76.5**	**20.8**	**1.6**	**0.87**

(Waqas, 2021)

2.2.3.2 Health Benefits

Camel meat offers several health advantages:

- Low Cholesterol: It contains lower cholesterol levels compared to beef, making it suitable for individuals with heart conditions (Joanna stadnik, 2024).

- Rich in Minerals: High concentrations of iron and zinc support anemia prevention and immune health (Baba et al., 2021).

- L-Carnitine: Camel meat is one of the best sources of L-carnitine, which aids in energy metabolism and muscle recovery (Isam T. Kadim, et al,2022).

2.2.3.3 Sustainability and Cultural Significance

Camel farming is environmentally sustainable, as camels thrive in arid climates with minimal water and feed requirements. Camel meat also holds cultural and economic significance in many regions, enhancing its appeal (Baba et al., 2021).

2.2.3.4 Food safety

Camel meat is a staple food source in many arid regions, particularly in the Middle East, North Africa, and parts of Asia. It is renowned for its nutritional benefits, such as being low in fat and rich in essential nutrients, which has contributed to its growing global popularity. However, like any other type of meat, camel meat raises concerns about safe handling, storage, and consumption, making it essential to understand these risks to ensure consumer safety (Boubker Nasser et al, 2015).

2.2.3.4.1 Risks

Camel meat can be exposed to contamination during slaughter or transportation due to unhygienic practices. For instance, slaughtering in open areas and insufficient refrigeration can lead to quick spoilage. Research highlights that poor storage conditions, such as using unclean carts, increase the risk of contamination by molds and bacteria (Boubker Nasser et al, 2015).

2.2.3.4.2 Allergies

Although rare, camel meat can cause allergic reactions in some individuals. Such cases may be related to specific proteins found in the meat. People with known sensitivities to other types of meat are advised to undergo proper testing before consuming camel meat (Mohamed-Yousif et al ,2024).

2.2.3.4.3 Contamination

In some regions, camel meat has been found to contain heavy metals such as lead due to environmental pollution. Consuming contaminated meat in large quantities may lead to long-term health issues, emphasizing the need for stricter regulation of production conditions and better environmental management (Mohamed-Yousif et al ,2024).

2.2.3.4.4 Diseases

Raw or undercooked camel meat can harbor harmful bacteria such as *Salmonella* and *E. coli*, which can cause food borne illnesses. It is crucial to cook camel meat thoroughly and avoid unsafe storage and transportation practices that elevate contamination risks (Mohamed-Yousif et al ,2024).

CHAPTER THREE

MATERIALS AND METHODS

Total Protein Estimation by Lowry's Method

3.1 the study area:

The city of Riyadh is capital of KSA, coordinates of Riyadh are approximately (24.7136° N, 46.6753° E). Imam Muhammad Ibn Saud Islamic University, in Biology lab

3.2 Samples collection:

Samples were collected from markets in Riyadh city.

3.3 Sample

- Camel meat
- Beef
- Insect larvae

Figure (3.1): samples of Beef, Insect larvae, Camel meat.

Figure (3.2): Sample Preparation in Centrifuge

3.4 Reagents Required

1. BSA stock solution (1mg/ml),

2. Analytical reagents:

(a) 50 ml of 2% sodium carbonate mixed with 50 ml of 0.1 N NaOH solution (0.4 gm in 100 ml distilled water.)

(b) 10 ml of 1.56% copper sulphate solution mixed with 10 ml of 2.37% sodium potassium tartarate solution. Prepare analytical reagents by mixing 2 ml of (b) with 100 ml of (a)

3. Folin - Ciocalteau reagent solution (1N) Dilute commercial reagent (2N) with an equal volume of water on the day of use (2 ml of commercial reagent + 2 ml distilled water).

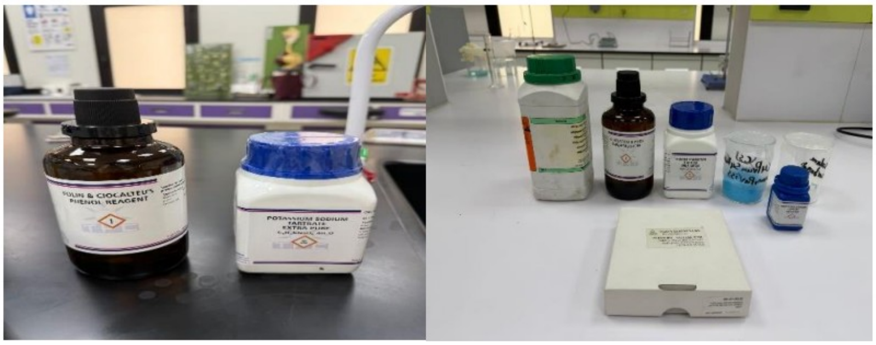

Figure (3.3): Folin , filter paper , BSA and other reagents

3.5 Principle

The phenolic group of tyrosine and trytophan residues (amino acid) in a protein will produce a blue purple color complex, with maximum absorption in the region of 660 nm wavelength, with Folin- Ciocalteau reagent which consists of sodium tungstate molybdate and phosphate. Thus the intensity of color depends on the amount of these aromatic amino acids present and will thus vary for different proteins. Most proteins estimation techniques use Bovin Serum Albumin (BSA) universally as a standard protein, because of its low cost, high purity and ready availability. The method is sensitive down to about 10 µg/ml and is probably the most widely used protein assay despite its being only a relative method , subject to interference from Tris buffer, EDTA, nonionic and cationic detergents, carbohydrate, lipids and some salts. The incubation time is very critical for a reproducible assay. The reaction is also dependent on pH and a working range of pH 9 to10.5 is essential.

3.6 Procedure

1. Different dilutions of BSA solutions are prepared by mixing stock BSA solution (1 mg/ ml) and water in the test tube. The final volume in each of the test tubes is 5 ml.

2. From these different dilutions, pipette out 0.2 ml protein solution to different test tubes and add 2 ml of alkaline copper sulphate reagent (analytical reagent). Mix the solutions well.

3. This solution is incubated at room temperature for 10 mins.

4. Then add 0.2 ml of reagent Folin Ciocalteau solution (reagent solutions) to each tube and incubate for min. Zero the colorimeter with blank and take the optical density (measure the absorbance) at 660nm.

5. Plot the absorbance against protein concentration to get a standard calibration curve.

6. Check the absorbance of unknown sample and determine the concentration of the unknown sample using the standard curve plotted above (Lowry,1951).

Figure (3.4): Measurement 20g of Na2CO3 in 500ml of H2O

Figure (3.5): measurement 1g of $KNaC_4H_4O_6.H_2O$ in 100ml H_2O

Figure (3.6): Spectrophotometers device

Figure (3.7): Refractometer device

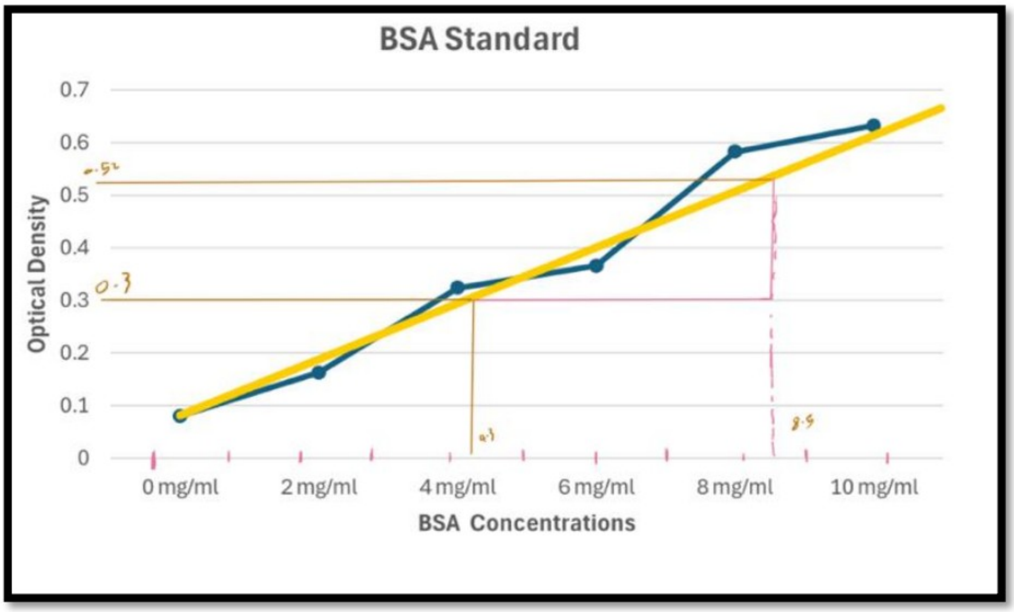

Figure (3.8): BSA Standard curve

Table 3.1: Optical density results from samples in the spectrophotometer

Replicate\ Sample	Camel	Insect	Beef
1	0.201	0.401	0.621
2	0.190	0.399	0.619
3	0.200	0.398	0.610
Average	0.197	0.399	0.616

Data:

-Optical Density of the Average of the Samples

y=

1)Camel meat (0.197)

2)Insect(0.399)

3) Beef(0.616)

- C= 0.07

- $m = \frac{y2-y1}{x2-x1} = \frac{0.52-0.3}{8.5-4.3} = 0.052$

- Buffer (10ml) , sample wight (1g)

$$\boldsymbol{X = \frac{y-c}{m}}$$

$$\boldsymbol{x1} = \frac{0.197-0.07}{0.052} = \boldsymbol{2.44}$$

$$\boldsymbol{x2 = \frac{0.399-0.07}{0.052} = 6.32}$$

$$\boldsymbol{x3 = \frac{0.616-0.07}{0.052} = 10.5}$$

Total Protein		**Protein content**	
X $*$ Buffer vol.		$\frac{Total\ protein}{sample\ wight}$	
Total protein of			
1)camel meat	2.44*10 =24.4 mg	1)camel meat	24.4/1=24.4 mg/g
2)Beef	6.32*10=63.2 mg.	2)Beef.	63.2/1=63.2 mg/g
3) Insect	10.5*10=105 mg.	3) Insect.	105/1=105 mg/g

3.7 Index of Nutritional Quality

One of the nutritional methods that can be used for both qualitative and quantitative evaluation of foods and diets is the Index of Nutritional Quality (INQ). A key advantage of INQ is that this method allows for the analysis of individual diets, meals, and foods in both qualitative and quantitative terms. Additionally, compared to alternative methods, INQ adjusts for the effect of energy intake in its calculation. INQ is expressed as a fraction, where the numerator and denominator represent the percentage of nutrient intake and the percentage of average dietary calorie requirements, respectively. INQ is considered simple and accurate in comparison to other methods, as it accounts for the effects of energy intake (Jalali, 2022).

- INQ = (protein + fats + carbohydrates + fiber + vitamin B12 + iron + zinc + calcium) / 8

3.8 Refractometer Device

A refractometer is a device that measures the refraction of light in a liquid, which is influenced by the concentration of dissolved substances. When measuring total protein, it determines the protein concentration in a sample by assessing how light bends as it passes through the liquid. This tool is often used in medical and veterinary settings to assess protein levels in blood or other bodily fluids (Skoog, 2014).

3.9 Statistical analysis

Data analysis was perform using excel version 17r presented data as mean standard error in figures and tables .

CHAPTER FOUR

THE RESULTE

For adsorption studies of BSA with silver nanoparticles different concentrations of BSA (0.05%, 0.15%, 0.25%, 0.35%, 0.45%, 0.55%, 0.75% and 0.85%) (Ravindran, 2010) .The results obtained by current study was support with the results found in previous study . (see Table 4.1)

Table 4.1: Bovine Serum Albumin (BSA) Standard

Sample	0mg/ml	2mg/ml	4mg/ml	6mg/ml	8mg/ml	10mg/ml
1	0.078	0.23	0.70	0.24	0.86	0.93
2	0.082	0.07	0.07	0.67	0.69	0.24
3	0.080	0.19	0.21	0.19	0.20	0.73
Average	0.0800	0.1630	0.3240	0.3660	0.5830	0.6326

Table 4.2: Total protein for calculate protein content

Sample	Total protein
BSA	108.19mg
Camel	24.4 mg
Insect	63.2 mg
Beef	105 mg

As shown in the protein profiles of the meat samples, the higher protein degradation could have occurred because of the protein oxidation during storage, which could have led to the fragmentation and lysis of structural proteins ,Generally, a mild degradation of the beef protein was revealed compared with that of camel meat (Maqsood, 2015). Protein extractability was found to be higher in beef (Soltanizadeh, 2008). Camel meat has been widely studied for its nutritional profile. While it is a good source of protein, it contains less protein compared to both beef and insects. Beef is known for its high protein content, largely due to its muscle structure, making it one of the richest sources of protein in animal meats. Insects, on the other hand, offer an even higher concentration of protein, particularly in species such as crickets and grasshoppers, which are considered efficient protein sources (Aljumaah,2014). The results obtained by current study was consistently with the results found in previous study. (See Table 4.2)

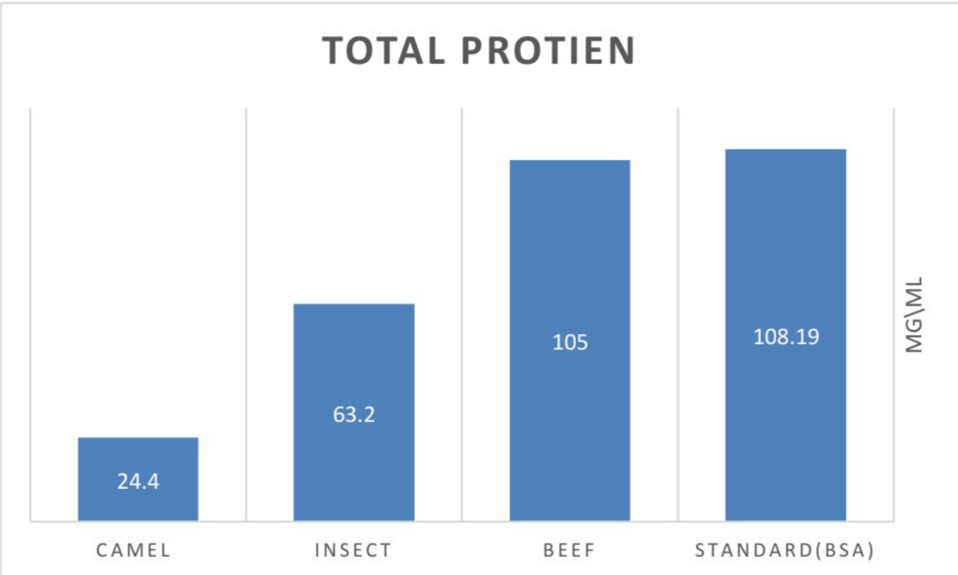

Figure 4.1: Total protein comparison of average concentration.

Table 4.3: Optical Density (OD) results from samples in the spectrophotometer

Replicate\ Sample	Camel	Insect	Beef
1	0.201	0.401	0.621
2	0.190	0.399	0.619
3	0.200	0.398	0.610
Average	0.197	0.399	0.616

Insects are essentially animals, and their consumption is an act of ingesting food of animal origin, where the higher levels of nutrients are protein and fat. In comparison, edible insects have higher energy, protein, fat, polyunsaturated fatty acids, and cholesterol than animal flesh and a higher variety and content of trace elements than meat (Orkusz, 2021). Some studies have shown that red meat consumption may increase the risk of stroke, diabetes, colon cancer, and lung cancer (Kromhout *et al.*, 2016). When compared with meat, insects seem to be more nutritious and healthier than food. Not only that, but insects are also still very diverse in terms of their nutritional content. Some statistics showed that insects are healthier than meat (Payne *et al.*, 2016). For this reason, insects are considered to be a meat substitute. For people who are over-nourished, eating insects may exacerbate the over-nutrition, but in cases of malnutrition, eating insects may be a good source of supplementary nutrients (Payne *et al.*, 2016). The results obtained by current study was consistently with the results found in previous study.

Results of the study that determined the protein content of beef using Spectrophotometer:

Average Protein Content: The raw protein content in beef ranged from 20% to 24%, depending on factors like whether the meat was fresh or processed, and the storage conditions post-slaughter.

Accuracy: The measurements were validated by comparing the results with traditional chemical analysis, showing a high correlation between both methods, which highlights the accuracy of spectrophotometric analysis for measuring protein (Savoia et al. 2021). The results obtained by current study was support with the results found in previous study (See Table:4.2).

More than 2000 species of edible insects are consumed around the world (Jongema, 2017). The most commonly consumed groups of insects include beetles, caterpillars, bees, wasps, ants, grasshoppers, locusts, crickets, true bugs, dragonflies, termites, flies, cockroaches, spiders, and others (Jongema, 2017). According to a study measuring larvae protein constituents, the findings were consistent with the results of previous studies (Orkusz, 2021; see Figure 4.4).

The comparative analysis conducted on the composition of meat from slaughtered animals and insects could not conclusively determine that insects have higher nutritional value, as the content of individual nutrients varies significantly between meat and insects (Orkusz, 2021; see Table 4.2).

Camel meat, although nutritious, has a relatively lower protein content compared to these other two sources. This can be attributed to factors such as the animal's physiology and its typical diet. While it remains a valuable protein source, its protein concentration does not match that of beef or insects (Aljumaah, 2014). The results obtained by current study was similary with the results found in previous study . (see Table 4.2)

Table 4.4: Refractometer sample results

Sample	Results
Standard	820
Beef	700
Insect	620
Camel	710

Table 4.5: Comparison between Spectrophotometer and Refractometer devices.

Average	Spectrophotometer (mg)	Refractometer (mg)
Standard	108.19	820
Beef	105	700
Insect	63.2	620
Camel	24.4	710

Table 4.6: Index of Nutritional Quality sample results.

Sample	Results
Beef	**13.235**
Insect	**8.165**
Camel	**3.155**

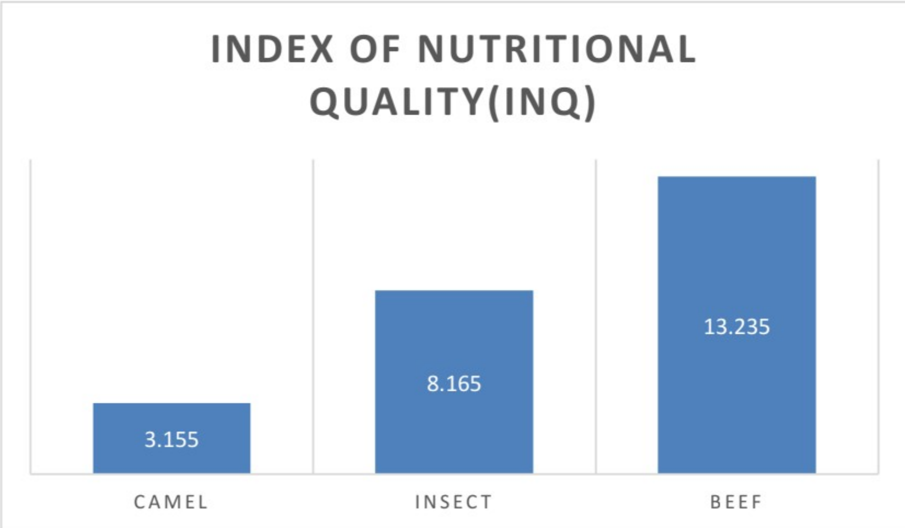

Figure 4.2: INDEX OF NUTRITIONAL QUALITY(INQ) results .

Conclusion

This study successfully evaluated and compared the nutritional profiles of beef, camel meat, and larvae as protein sources, highlighting their respective health benefits and sustainability potential. The findings revealed that beef has the highest nutritional value, while larvae offer a sustainable and nutrient-dense alternative. Camel meat, although lower in protein concentration, remains a valuable option due to its low fat and cholesterol levels, making it a healthier choice for specific populations. The results emphasize the importance of exploring alternative protein sources, such as insects, to address the growing demand for sustainable and nutritious food or feed systems. By integrating advanced research methodologies and focusing on species with higher nutritional profiles, future studies can provide actionable insights to combat global food security challenges and promote healthier, more sustainable diets

Recommendations

This study used crickets larvae as a protein source to evaluate nutritional content and health benefits. For future research, it is recommended to explore other whole insect species such as grasshoppers, Wasps and crickets. These species are recognized for their higher protein content, richer nutritional profiles, and broader cultural acceptance as edible sources. Moreover, grasshoppers and crickets demonstrate superior sustainability metrics, requiring fewer resources while producing lower environmental impacts.

Expanding the variety of insect species examined in future studies will provide a more comprehensive understanding of their nutritional and environmental advantages.

Additionally, refining analytical methodologies to assess key components like essential amino acids, fatty acids, and micronutrients will enhance the accuracy and applicability of the findings. Such advancements would further support the integration of sustainable insect proteins into global food and feed systems.

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