UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DIETARY EDIBLE BIRD'S NEST SUPPLEMENTATION ON COGNITIVE FUNCTION OF TRANSGENERATIONAL MICE

OBAIDULLAH MAHAQ

FPV 2021 1

EFFECTS OF DIETARY EDIBLE BIRD'S NEST SUPPLEMENTATION ON COGNITIVE FUNCTION OF TRANSGENERATIONAL MICE

By

OBAIDULLAH MAHAQ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Veterinary Science

November 2020

DEDICATION

To my beloved mother and my loving father who was always wishful thinking of my higher education. To the pillar of my strength my spouse for your endless attention, love and devotion in my life and cute sons (Subhanullah, Habibullah and Hozaifa), your invaluable love and support were my main motivations for completing my master journey. I am really astonished by your patience in bearing my absence for more than two years. My heartfelt thoughts also go to my siblings, who are always honestly happy with my progress.

To my academic family in Afghanistan, let us aspire to restore our nation to its former glory, as the centre of knowledge and grandeur that it once was.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Veterinary Science

EFFECTS OF DIETARY EDIBLE BIRD'S NEST SUPPLEMENTATION ON COGNITIVE FUNCTION OF TRANSGENERATIONAL MICE

By

OBAIDULLAH MAHAQ

November 2020

Chairman : Associate Profesor Hafandi Ahmad, PhD
Faculty : Veterinary Medicine

Edible bird's nest (EBN) is well known as a natural food product rich in glycoproteins such as sialic acid, minerals, and essential amino acids. Evidence from epidemiological studies suggests that EBN dietary supplementation improved brain cognitive functions. In mammals, the highest absorption of sialic acid from EBN occurs in the brain where it participates as an integral part of ganglioside structure in synaptogenesis and neural transmission. Sialic acid in EBN is vital during rapid brain growth particularly for preterm infants. While EBN dietary supplementation has been associated to enhance brain functions in infants, the effects of multiple generations of dietary EBN on cognitive function remain unclear. Thus, this study aimed to determine the effects of dietary EBN supplementation from different locations (e.g south (S) and north (N) of Peninsular Malaysia, Sabah (B) and commercial (C) on the cognitive function of transgenerational mice. To address these issues, C57BL/6 breeder mice (F0) were fed with different sources of EBN for six weeks (10 mg/kg) using oral gavage. Then, all animals were bred to obtain first generation (F1) until the second generation (F2) animals. At six weeks of age, F1 and F2 animals were tested for brain cognitive function by Y-maze test. Histological study for neuron density and distribution were analyzed using the hematoxylin and eosin procedure. The active compounds of EBN were determined using HPLC and the brain genes expression associated with cognitive function (e.g GNE, ST8SiaIV, SLC17A5, and BDNF mRNA) were analyzed using real-time PCR. Results showed that dietary EBN supplementation improved cognitive performance of F0, F1 and F2 mice by significantly increased the number of entries (9.04 ± 0.15; $P < 0.05$) and the time spent (2.40 ± 0.4 min; $P < 0.05$) in the novel arm of Y-maze test compared to control. This could indicate that the breeder mice (F0) absorbed sialic acid from EBN which crossed the placenta to contribute fetal brain function and development in the third trimester. In addition, EBN supplementation improved neuron development in the brain hippocampus of F0, F1 and F2 generations by significantly increased the number of neurons (32.74 ± 4.80; $P < 0.05$) compared to control (21.78 ± 2.86). In PCR analysis,

mice maintained on EBN supplementation significantly increased the expression level of GNE (1.6-fold; $P < 0.05$) in both F0 and F1 of EBN-N group. Interestingly, this gene was upregulated only in F1 mice (1.64-fold) especially in the EBN-C group. Expression level of ST8SiaIV was significantly increased (2-fold; $P < 0.05$) in the F0 of EBN-N group and in the F1 of EBN-C group (1.83-fold). The BDNF levels were significantly increased in EBN-S (2-fold; $P < 0.05$), EBN-N (1.5-fold) and EBN-C (1.6-fold) F1 animals compared to control (1-fold). However, SLC17A5 expression was not significantly increased ($P > 0.05$) in all groups of F0 and F1 animals. These results indicate that increased number of neurons and the variation level of genes expression due to the presence and metabolism of sialic acid in mammals associates with increased cognitive performance. In conclusion, EBN extract supplementation for six weeks with higher sialic acid content improve the cognitive function of transgenerational mice.

Keywords: Edible bird's nest (EBN), cognitive function, neuron density, gene expression, transgenerational mice

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Veterinari Sains

KESAN SUPLEMEN SARANG BURUNG YANG BOLEH DIMAKAN PADA FUNGSI KOGNITIF TIKUS TRANSGENERASI

Oleh

OBAIDULLAH MAHAQ

November 2020

Pengerusi : Profesor Madya Hafandi Ahmad, PhD
Fakulti : Perubatan Veterinar

Sarang burung yang boleh dimakan (EBN) dikenali sebagai produk makanan semulajadi yang kaya dengan glikoprotein seperti asid sialik, mineral dan asid amino penting. Bukti dari kajian epidemiologi menunjukkan bahawa suplemen makanan dari EBN meningkatkan fungsi kognitif otak. Di dalam mamalia, penyerapan tertinggi EBN berlaku di otak di mana ia mengambil bahagian penting bagi struktur gangliosid di dalam sinaptogenesis dan transmisi saraf. Asid sialik dalam EBN sangat penting semasa pertumbuhan otak yang cepat terutama bagi bayi prematur. Walaupun suplemen makanan EBN dikaitkan untuk meningkatkan fungsi otak pada infan, kesan pemakanan EBN pada fungsi kognitif melalui beberapa generasi adalah tidak jelas. Oleh itu, kajian ini bertujuan untuk mengetahui kesan suplemen EBN dari lokasi yang berlainan (cth. selatan (S) dan utara (N) Semenanjung Malaysia, Sabah (B) dan komersial (C) terhadap fungsi kognitif tikus dalam beberapa generasi. Bagi menangani isu ini, tikus pembiakan CJ57BL/6 diberi makan dengan sumber EBN yang berbeza (10 mg/kg) menggunakan oral gavaj. Kemudian, semua haiwan dibiak untuk mendapatkan generasi pertama (F0) haiwan sehingga generasi kedua (F2) haiwan. Pada usia 6 minggu, haiwan F1 dan F2 diuji bagi fungsi kognitif otak menggunakan ujian Y-maze. Kajian histologi bagi ketumpatan dan keselarakan sel neuron dianalisis menggunakan prosedur haematoxylin dan eosin. Aktif kompaun bagi EBN ditentukan menggunakan HPLC dan ekspresi gen otak yang berkaitan dengan fungsi kognitif (cth. GNE, ST8SiaIV, SLC17A5 dan BDNF mRNA) dianalisis dengan menggunakan real-time PCR. Hasil kajian menunjukkan bahawa suplemen pemakanan EBN meningkatkan prestasi kognitif tikus F0, F1 and F2 dengan peningkatan jumlah kemasukan secara signifikan (9.04 ± 0.15; $P < 0.05$) dan masa yang dihabiskan (2.40 ± 0.4 min; $P < 0.05$) di bahagian novel bagi ujian Y-maze berbanding kumpulan kawalan. Ini dapat menunjukkan bahawa tikus F0 menyerap asid sialik dari EBN yang melintasi plasenta bagi menyumbang fungsi dan perkembangan otak janin pada trimester ke tiga. Sebagai tambahan, suplemen EBN meningkatkan perkembangan neuron di hipokampus otak pada generasi F0, F1 dan F2 dengan peningkatan bilangan

neuron yang signifikan (32.74 ± 4.80; $P < 0.05$) berbanding dengan kumpulan kawalan (21.78 ± 2.86). Dalam analisis PCR, tikus yang dikekalkan pada suplementasi EBN secara signifikan meningkatkan tahap ekspresi GNE (1.6-kali ganda; $P < 0.05$) pada kedua-dua F0 dan F1 dari kumpulan EBN-N. Menariknya gen ini meningkat pada tikus F1 (1.64-kali ganda) terutamanya pada kumpulan EBN-C. Tahap ekspresi ST8SiaIV meningkat dengan ketara (2 kali ganda; $P < 0.05$) pada kumpulan F0 EBN-N dan dalam kumpulan F1 EBN-C (1.83-kali ganda). Tahap BDNF meningkat dengan ketara pada haiwan EBN-S (2 kali ganda; $P < 0.05$), EBN-N (1.5-kali ganda) dan EBN-C (1.6-kali ganda) berbanding dengan kumpulan kawalan (1-kali ganda). Walaubagaimanapun, ekspresi SLC17A5 tidak meningkat secara signifikan ($P > 0.05$) pada semua kumpulan haiwan F0 dan F1. Hasil kajian ini menujukkan bahawa peningkatan bilangan neuron dan tahap variasi ekspresi gen adalah kerana kehadiran dan metabolisme asid sialik pada mamalia berkaitan dengan peningkatan prestasi kognitif. Kesimpulannya, suplemen ekstrak EBN dengan kandungan sialik asid yang tinggi selama enam minggu meningkatkan fungsi kognitif tikus transgenerasi.

Kata kunci: Sarang burung yang boleh di makan (EBN), fungsi kognitif, kepadatan neuron, ekspresi gene, tikus transgenerasi

ACKNOWLEDGEMENTS

First, of all, I would like to give thanks and praise to almighty Allah, and my parents for their countless support and encouragement during my studies.

My deepest appreciation goes to my supervisor, Assoc. Prof. Dr. Hafandi Ahmad and my co-supervisors Assoc. Prof. Dr. Mohd Hezmee Mohd Noor and Assoc. Prof. Dr. Hasliza Abu Hassim for their support in my master journey. Assoc. Prof. Dr. Hafandi Ahmad taught me the skills of designing and performing scientific research work that are of the highest quality. In addition, he has provided me with encouragement and advice whenever I needed them. I am also grateful to my co-supervisors, Assoc. Prof. Dr. Mohd Hezmee Mohd Noor and Assoc. Prof. Dr. Hasliza Abu Hassim who often took time off from their busy schedules to discuss with me on my research work. Through these discussions, I was able to obtain useful scientific advice and knowledge which greatly aids in my understanding on the field of animal physiology. I would also like to express my gratitude to the Higher Education Development Program (HEDP) and the Ministry of Higher Education of Afghanistan for providing me with the research scholarship for my master's degree studies.

Next, I would like to thank the Centre of Excellence (CoE) Swiftlets, Faculty of Veterinary Medicine, Universiti Putra Malaysia, Department of Veterinary Services Malaysia, and Ministry of Science and Technology (MOSTI) Malaysia (Project Number: 6371401-10301) for providing the grant for the project of edible bird's nest. Throughout the course of my master's program, it has been a great pleasure to work with the post-graduates from Anatomy laboratory, Mr. Mohd Adha P. Rameli, Mrs. Rosmawati Mohd Hanipah from physiology laboratory and Mrs. Nur Farhana Harun from nutrition laboratory. Without them, I am certain that my research work would not have proceeded so smoothly. I am grateful to all their assistance and wish them the best of luck in the future. Also, I would like to thank Mr. Mohd Qayyum and other EBN industries for their assistance in obtaining the edible bird's nest from South and North Peninsular Malaysia as well as Sabah. In addition, I wish to express my thanks to Mr. Saipuzaman Ali and Mr. Mohd Jamil Samad from the Serology laboratory for their valuable technical advice and training in the analytical instruments.

Last but not least, I am always grateful to my friends for their continuous support and understanding throughout the journey of my master's program.

Finally, my deepest gratitude goes to my dear parents my wife and all family for their understanding, financial and moral support.

Thank you to everyone who had contributed direct or indirectly in making this research successful.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Veterinary Science. The members of the Supervisory Committee were as follows:

Hafandi bin Ahmad, PhD
Associate Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Chairman)

Mohd Hezmee bin Mohd Noor, PhD
Associate Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Member)

Hasliza Binti Abu Hassim, PhD
Associate Professor
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 February 2021

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AChE	Acetylcholinesterase
AD	Alzheimer's Disease
ALDH	Aldehyde dehydrogenase
BDNF	Brain Derived Neurotrophic Factor
CA-1	Cornu Ammonis-1
CALM	Calmodulin
cDNA	Complementary Deoxyribonucleic acid
ChAT	Choline acetyltransferase
CTRL	Control
DG	Dentate gyrus
DP	Degree of polymerization
EBN	Edible Bird's Nest
EBN-B	Edible Bird's Nest collected from Borneo
EBN-C	Edible Bird's Nest Commercial
EBN-N	Edible Bird's Nest collected from North
EBN-S	Edible Bird's Nest collected from South
EGF	Epidermal Growth Factor
EGFR	Epidermal Growth Factor Receptor
ERK	Extracellular signal-regulated protein kinase
F0	Generation 0 (Maternal mice)
F1	First Generation
GAPDH	Glyceraldehyde 3-phosphate dehydrogenase
GNE	UDP-N-acetylglucosamine 2-epimerase/ N-acetylmannosamine kinase
Gpx	Glutathione peroxidase

Gsr	Glutathione reductase
H&E	Hematoxylin and Eosin
HPLC	High performance liquid chromatography
HSD	Honestly Significant Difference
IL-6	Interleukin-6
JNK	c-Jun N-terminal kinases
MDA	Malondialdehyde
MFGM	Milk fat globule membrane
MMP-1	Matrix metalloproteinase-1
NCAM	Neuro Cellular Adhesion Molecule
P4R	Progesterone 4 Receptor
PAGE	Polyacrylamide Gel Electrophoresis
PCNA	Proliferating Cell Nuclear Antigen
PUFA	Poly Unsaturated Fatty Acid
qPCR	quantitative Polymerase Chain Reaction
SDS	Sodium Dodecyl Sulfate
SIRT1	Sirtuin 1/NAD-dependent deacetylase sirtuin-1
SLC17A5	Sialin/sialic acid cotransporter
SNCA	α-Synuclein
SOD	Superoxide Dismutase
ST8SiaIV	CMP-N-acetylneuraminate-poly-alpha-2,8-sialyltransferase
TNF-α	Tumor necrosis factor-alpha
TTR	Transthyretin
VEGF	Vascular Endothelial Growth Factor

CHAPTER 1

INTRODUCTION

Edible bird's nest (EBN) is a type of medicinal food secreted by the salivary glands of swiftlets (Ma & Liu, 2012). For several centuries, EBN has been used in traditional Chinese medication or as dietary supplements. Until now, it has also been consumed as a health-supportive substance to provide nutrients and reinstate body deficiency (Nabilah et al., 2018). The EBN has now been developed into different types of food products, including drinks and food additives. It is now also being used as a cosmetic ingredient (F. Ma & Liu, 2012). Although, it is one of the most expensive and popular food in the world but its compositional properties are remain debated among the researchers (Marcone, 2005). It is necessary to investigate the relationships of ingredients and biological functions of the EBN, which are yet to be determined (Ma & Liu, 2012). Mainly, EBN contains proteins, carbohydrates, amino acids, and mineral salts (Marcone, 2005). The carbohydrates are the second abundant components with a higher content of sialic acid found in EBN (Saengkrajang et al., 2013). It was suggested that sialic acid found in EBN is vitally important for brain cognitive function and neurological development (Rashed & Nazaimoon, 2010; Yew et al., 2014).

Cognitive functions are including perception, learning, memory and decision making, that contribute to foraging, walking, vocalizing, emotion and many others behaviors of daily life. In animals, the cognitive function described the exploration or spatial recognition in a novel environment (Shettleworth, 2001). The relative abundance of a particular diet or nutrients has long been recognized to influence cognitive function (Gómez-Pinilla, 2008). Dietary supplementation such as edible bird's nest considerably improve cognitive function and has a potent neuroprotection by inhibiting the mechanisms of neuroinflammation and oxidative stress in the brain and hippocampus (Careena et al., 2018). It has been reported that rats supplemented with EBN for 12 weeks improved water maze performance during four days consecutively trial and indicated that EBN dietary supplementation for 3 months could improve cognitive function and the memory of ovariectomized female rats (Hou et al., 2017). Recent studies suggest that maternal supplementation of EBN in the prenatal and early postnatal periods increases the level of sialic acid in the brain ganglioside of the offspring' which may contribute to the developing of cognitive function and learning efficiency (Xie et al., 2018). While dietary EBN supplementation has been associated to enhance brain functions in mammals, the multi-generation effects of dietary EBN supplementation on cognitive function are remain unclear. In addition, there is a paucity of information about the beneficial effects of maternal dietary EBN supplementation on brain cognitive function over several generations in mammals. Challenges in quantifying mental development in humans remained a major obstacle because of the long generation gap in humans makes it difficult to investigate the effects of maternal EBN dietary supplementation on brain development and cognitive function in their neonates. In this study, mice were used due to their features short reproductive cycle and gestation period. This enables the transgenerational effects of

EBN on mental health and cognitive function to be investigated thoroughly in this model. Therefore, the main objective of this study was to investigate the effects of multiple generations of dietary EBN supplementation on cognitive function in mice.

General objective

To study the influences of dietary EBN supplementation on brain cognitive function of transgenerational mice

Specific objectives

1. To determine the effects of different EBN extract supplementation on brain cognitive function of F0, F1 and F2 mice using the Y-maze task.
2. To determine the influence of maternal EBN dietary supplementation on brain neuron histological changes and distribution of F0, F1 and F2 mice.
3. To assess the influence of maternal EBN dietary supplementation on brain genes expression (e.g ST8SiaIV, GNE, SLC17A5 and BDNF) associated with the cognitive function of F0 and F1 mice.

Hypotheses

1. Dietary EBN supplementation improves cognitive function of transgenerational mice by transmitting the sialic acid component from EBN in the first and second generations.
2. Dietary EBN supplementation increases brain neuron density in the hippocampus of transgenerational mice.
3. Dietary EBN supplementation increases the levels of mRNA for GNE, SLC17A5, ST8SiaIV and BDNF in the brain hippocampus in F0 and F1 mice, as the likely basis for increased cognitive function and learning memory.

REFERENCES

Abdul Khalid, S., Rashed, A., Aziz, S., & Ahmad, H. (2019). Effects of sialic acid from edible bird nest on cell viability associated with brain cognitive performance in mice. *World Journal of Traditional Chinese Medicine*, *5*(4), 214.

Ahmad, H., Ong, S.-Q., & Tan, E. H. (2019). The diet for edible-nest swiftlets: nutritional composition and cost of life stages of megaselia scalaris loew (*Diptera: Phoridae*) bred on 3 commercial breeding materials . *International Journal of Insect Science*, *11*, 1–5.

Aiken, C. E., Tarry-Adkins, J. L., & Ozanne, S. E. (2016). Transgenerational effects of maternal diet on metabolic and reproductive ageing. *Mammalian Genome*, *27*(7–8), 430–439.

Albishtue, A. A., Yimer, N., Zakaria, M. Z. A., Haron, A. W., Babji, A. S., Abubakar, A. A., & Almhanawi, B. H. (2019). Effects of EBN on embryo implantation, plasma concentrations of reproductive hormones, and uterine expressions of genes of PCNA, steroids, growth factors and their receptors in rats. *Theriogenology*, *126*, 310–319.

Anacker, C., & Hen, R. (2017). Adult hippocampal neurogenesis and cognitive flexibility-linking memory and mood. *Nature Reviews Neuroscience*, *18*(6), 335–346.

Aswir, A. R. and Wan Nazaimoon, W. M. (2011). Effect of edible bird ' s nest on cell proliferation and tumor necrosis factor- alpha (TNF-α) release in vitro. *International Food Research Journal*, *18*(3), 1123–1127.

Asztely, F., Kokaia, M., Olofsdotter, K., Örtegren, U., & Lindvall, O. (2000). Afferent-specific modulation of short-term synaptic plasticity by neurotrophins in dentate gyrus. *European Journal of Neuroscience*, *12*(2), 662–669.

Balogh, S. A., & Wehner, J. M. (2003). Inbred mouse strain differences in the establishment of long-term fear memory, *140*(2–6), 97–106.

Baptista, P., & Andrade, J. P. (2018). Adult hippocampal neurogenesis: Regulation and possible functional and clinical correlates. *Frontiers in Neuroanatomy*, *12*(6), 1–23.

Bardor, M., Nguyen, D. H., Diaz, S., & Varki, A. (2005). Mechanism of uptake and incorporation of the non-human sialic acid N-glycolylneuraminic acid into human cells. *Journal of Biological Chemistry*, *280*(6), 4228–4237.

Bathina, S., & Das, U. N. (2015). Brain-derived neurotrophic factor and its clinical Implications. *Archives of Medical Science*, *11*(6), 1164–1178.

Benraiss, A., Chmielnicki, E., Lerner, K., Roh, D., & Goldman, S. A. (2001). Adenoviral brain-derived neurotrophic factor induces both neostriatal and olfactory neuronal recruitment from endogenous progenitor cells in the adult forebrain. *Journal of Neuroscience*, *21*(17), 6718–6731.

Binder, D. K., & Scharfman, H. E. (2004). Brain-derived Neurotrophic Factor. *Growth Factors*, *22*(3), 123–131.

Bork, K., Reutter, W., Gerardy-Schahn, R., & Horstkorte, R. (2005). The intracellular concentration of sialic acid regulates the polysialylation of the neural cell adhesion molecule. *FEBS Letters*, *579*(22), 5079–5083.

Brink, L. R., & Lönnerdal, B. (2018). The role of milk fat globule membranes in behavior and cognitive function using a suckling rat pup supplementation model. *Journal of Nutritional Biochemistry*, *58*, 131–137.

Brinks, V., Mark, M. Van Der, Kloet, R. De, & Oitzl, M. (2007). Emotion and cognition in high and low stress sensitive mouse strains : a combined neuroendocrine and behavioral study in BALB / c and C57BL / 6J mice. *Frontiers in Behavioral Neuroscience*, *1*(8), 1–8.

Buchman, A. S., Yu, L., Boyle, P. A., Schneider, J. A., De Jager, P. L., & Bennett, D. A. (2016). Higher brain BDNF gene expression is associated with slower cognitive decline in older adults. *Neurology*, *86*(8), 735–741.

But, P. P.-H., Jiang, R.-W., & Shaw, P.-C. (2013). Edible bird's nests—How do the red ones get red? *Journal of Ethnopharmacology*, *145*(1), 378–380.

Careena, S., Sani, D., Tan, S. N., Lim, C. W., Hassan, S., Norhafizah, M., … Lim, C. T. S. (2018). Effect of edible bird's nest extract on lipopolysaccharide-induced impairment of learning and memory in wistar rats. *Evidence-Based Complementary and Alternative Medicine*, *2018*, 1–7.

Chen, X., & Varki, A. (2010). Advances in the biology and chemistry of sialic acids. *ACS Chemical Biology*, *5*(2), 163–176.

Chen, Y., Zheng, Z., Zhu, X., Shi, Y., Tian, D., Zhao, F., … Wang, B. (2015). Lactoferrin promotes early neurodevelopment and cognition in postnatal piglets by upregulating the bdnf signaling pathway and polysialylation. *Molecular Neurobiology*, *52*(1), 256–269.

Chua, K.-H., Lee, T.-H., Nagandran, K., Md Yahaya, N. H., Lee, C.-T., Tjih, E. T. T., & Abdul Aziz, R. (2013). Edible Bird's nest extract as a chondro-protective agent for human chondrocytes isolated from osteoarthritic knee: in vitro study. *BMC Complementary and Alternative Medicine*, *13*(1), 19.

Chua, L. S., & Zukefl, S. N. (2016, November 1). A comprehensive review on edible bird nests and swiftlet farming. *Journal of Integrative Medicine, 14(6)*, *415–428*.

Coleman, J. R. I., Bryois, J., Gaspar, H. A., Jansen, P. R., Savage, J. E., Skene, N., … Breen, G. (2019). Biological annotation of genetic loci associated with intelligence in a meta-analysis of 87,740 individuals. *Molecular Psychiatry*, *24*(2), 182–197.

Colombo, J. P., Garcia-Rodenas, C., Guesry, P. R., & Rey, J. (2003). Potential effects of supplementation with amino acids, choline or sialic acid on cognitive development in young infants. *Acta Paediatrica, International Journal of Paediatrics, Supplement*, *92*(442), 42–46.

Cottrell, G. W., Greenway, J. C., Mayr, E., Paynter, R. A., Peters, J. L., & Traylor, M. A. (1940). Check-list of birds of the world. *Cambridge : Harvard University Press*, *4*, 220–221.

Cutuli, D. (2017). Functional and structural benefits induced by omega-3 polyunsaturated fatty acids during aging. *Current Neuropharmacology*, *15*(4), 534–542.

Daud, N. A., Yusop, S. M., Babji, A. S., Lim, S. J., Sarbini, S. R., & Yan, T. H. (2019). Edible bird ' s nest : physicochemical properties , production , and application of bioactive extracts and glycopeptides. *Food Reviews International*, *2*(1), 1–20.

Dauncey, M. J. (2014). Nutrition , environment and gene expression : impact on health , welfare and production. *Avian Nutrigenomics Course*, *2*(5), 27–28.

Dauncey, M. J., & Bicknell, R. J. (1999). Nutrition and neurodevelopment: mechanisms of developmental dysfunction and disease in later life. *Nutrition Research Reviews*, *12*(2), 231–253.

Davies, G., Armstrong, N., Bis, J. C., Bressler, J., Chouraki, V., Giddaluru, S., … Deary, I. J. (2015). Genetic contributions to variation in general cognitive function: A meta-analysis of genome-wide association studies in the CHARGE consortium (N=53 949). *Molecular Psychiatry*, *20*(2), 183–192.

Demirci, E., Guler, Y., Ozmen, S., Canpolat, M., & Kumandas, S. (2019). Levels of salivary sialic acid in children with autism spectrum disorder; Could it be related to stereotypes and hyperactivity? *Clinical Psychopharmacology and Neuroscience*, *17*(3), 415–422.

Deng, K., He, H., Qiu, J., Lorber, B., Bryson, J. B., & Filbin, M. T. (2009). Increased synthesis of spermidine as a result of upregulation of arginase I promotes axonal regeneration in culture and in vivo. *Journal of Neuroscience*, *29*(30), 9545–9552.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., … Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Medicine and Science in Sports and Exercise*, *48*(6), 1197–1222.

Dudchenko, P. A. (2004). An overview of the tasks used to test working memory in rodents. *Neuroscience and Biobehavioral Reviews*, *28*(7), 699–709.

Duncan, P. I., Raymond, F., Fuerholz, A., & Sprenger, N. (2009). Sialic acid utilisation and synthesis in the neonatal rat revisited. *PLoS ONE*, *4*(12), 1–10.

Dyall, S. C. (2015). Long-chain omega-3 fatty acids and the brain: A review of the independent and shared effects of EPA, DPA and DHA. *Frontiers in Aging Neuroscience*, *7*(APR), 1–15.

Fanselow, M. S., & Dong, H. W. (2010). Are the dorsal and ventral hippocampus functionally distinct structures? *Neuron*, *65*(1), 7–19.

Fjell, A. M., & Walhovd, K. B. (2010). Structural brain changes in aging: courses, causes and cognitive consequences. *Reviews in the Neurosciences*, *21*(3), 187–221.

Foley, A. G., Rønn, L. C. B., Murphy, K. J., & Regan, C. M. (2003). Distribution of polysialylated neural cell adhesion molecule in rat septal nuclei and septohippocampal pathway: transient increase of polysialylated interneurons in the subtriangular septal zone during memory consolidation. *Journal of Neuroscience Research*, *74*(6), 807–817.

Forny-Germano, L., Lyra e Silva, N. M., Batista, A. F., Brito-Moreira, J., Gralle, M., Boehnke, S. E., … De Felice, F. G. (2014). Alzheimer's disease-like pathology induced by amyloid-β oligomers in nonhuman primates. *The Journal of Neuroscience*, *34*(41), 13629–13643.

Fougerat, A., Pan, X., Smutova, V., Heveker, N., Cairo, C. W., Issad, T., … Pshezhetsky, A. V. (2018). Neuraminidase 1 activates insulin receptor and reverses insulin resistance in obese mice. *Molecular Metabolism*, *12*(4), 76–88.

Francis, D., Diorio, J., Liu, D., & Michael J. Meaney. (1999). Nongenomic transmission across generations of maternal behavior and stress responses in the rat. In *Foundations in Social Neuroscience* Vol. 286, pp. 1155–1158.

Gal, B., Ruano, M.-J., Puente, R., García-Pardo, L. A., Rueda, R., Gil, A., & Hueso, P. (1997). Developmental changes in udp-n-acetylglucosamine 2-epimerase activity of rat and guinea-pig liver. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, *118*(1), 13–15.

Garcia, Y., & Esquivel, N. (2018). Comparison of the response of male BALB/C and C57BL/6 mice in behavioral tasks to evaluate cognitive function. *Behavioral Sciences*, *8*(1), 1–14.

Goh, D. L. M., Chua, K. Y., Chew, F. T., Liang, R. C. M. Y., Seow, T. K., Ou, K. L., … Lee, B. W. (2001). Immunochemical characterization of edible bird's nest allergens. *Journal of Allergy and Clinical Immunology*, *107*(6), 1082–1088.

Goh, W. L., Siew, W. S., Davies, S. E. W., Ball, S., Khoo, G., Lim, C. K., … Cranbrook, E. of. (2018). Genetic diversity among white-nest swiftlets of the genus *Aerodramus* (*Aves : Apodidae : Collocaliini*) of house-farms in Malaysia. *Raffles Bulletin of Zoology*, *66*(6), 350–360.

Gomez-Pinilla, F. (2008). Brain foods: the effects of nutrients on brain function. *Nature Reviews Neuroscience*, *9*(7), 568–578.

Gosling, S. D. (2001). From mice to men: What can we learn about personality from animal research? *Psychological Bulletin*, *127*(1), 45–86.

Guo, C. T., Takahashi, T., Bukawa, W., Takahashi, N., Yagi, H., Kato, K., … Suzuki, Y. (2006). Edible bird's nest extract inhibits influenza virus infection. *Antiviral Research*, *70*(3), 140–146.

Guo, L., Wu, Y., Liu, M., Wang, B., Ge, Y., & Chen, Y. (2017). Determination of edible bird's nests by FTIR and SDS-PAGE coupled with multivariate analysis. *Food Control*, *80*, 259–266.

Hafandi, A., Begg, D. P., Premaratna, S. D., Sinclair, A. J., Jois, M., & Weisinger, R. S. (2014). Dietary repletion with ω3 fatty acid or with COX inhibition reverses cognitive effects in F3 ω3 fatty-acid-deficient mice. *Comparative Medicine*, *64*(2), 106–109.

Halimi, N. M., Kasim, Z. M., & Babji, A. S. (2014). Nutritional composition and solubility of edible bird nest (*Aerodramus fuchiphagus*). In *AIP Conference Proceedings*. Vol. 1614, pp. 476–481.

Hao, Q., & Rahman, A. (2016). Swiftlets and edible bird's nest industry in Asia. *PJSRR Pertanika Journal of Scholarly Research Reviews*, *2*(1), 32–48.

Harduin-Lepers, A., Mollicone, R., Delannoy, P., & Oriol, R. (2005). The animal sialyltransferases and sialyltransferase-related genes: A phylogenetic approach. *Glycobiology*, *15*(8), 805–817.

Hedden, T., & Gabrieli, J. D. E. (2004). Insights into the ageing mind: a view from cognitive neuroscience. *Nature Reviews Neuroscience*, *5*(2), 87–96.

Hinderlich, S., Weidemann, W., Yardeni, T., Horstkorte, R., & Huizing, M. (2013). UDP-GlcNAc 2-Epimerase/ManNAc Kinase (GNE): a master regulator of sialic acid synthesis. *Topics in Current Chemistry*.Vol. 366, pp. 97–137.

Hiratsuka, S., Honma, H., Saitoh, Y., Yasuda, Y., & Yokogoshi, H. (2013). Effects of dietary sialic acid in n-3 fatty acid-deficient dams during pregnancy and lactation on the learning abilities of their pups after weaning. *Journal of Nutritional Science and Vitaminology*, *59*(2), 136–143.

Hobbs, J. J. (2004). Problems in the harvest of edible birds' nests in Sarawak and Sabah, Malaysian Borneo. *Biodiversity and Conservation*, *13*(12), 2209–2226.

Holtzman, D. M., & Lowenstein, D. H. (1995). Selective inhibition of axon outgrowth by antibodies to NGF in a model of temporal lobe epilepsy. *Journal of Neuroscience*, *15*(11), 7062–7070.

Hong, T. K., Choy, C. F., & Kiat, A. O. H. (2018). Approach to improve edible bird nest quality & establishing better bird nest cleaning process facility through best value approach. *Journal for the Advancement of Performance Information and Value*, *10*(1), 38–50.

Hou, Z., He, P., Imam, M. U., Qi, J., Tang, S., Song, C., & Ismail, M. (2017). Edible bird's nest prevents menopause-related memory and cognitive decline in rats via increased hippocampal sirtuin-1 expression. *Oxidative Medicine and Cellular Longevity*, *2017*, 1–8.

Howe, C., Lee, L. T., & Rose, H. M. (1961). *Collocalia mucoid*: A substrate for myxovirus neuraminidase. *Archives of Biochemistry and Biophysics*, *95*(3), 512–520.

Huang, C., Seino, J., Wang, L., Haga, Y., & Suzuki, T. (2015). Autophagy regulates the stability of sialin, a lysosomal sialic acid transporter. *Bioscience, Biotechnology and Biochemistry, 79*(4), 553–557.

Ibrahim, S. H., Teo, W. C., & Baharun, A. (2009). A study on suitable habitat for swiftlet farming. *Journal of Civil Engineering, Science and Technology*, *1*(1), 1–7.

Idris, A., Abdullah, A.-A., & Abd-Rehman, M. (2014). An overview of the study of the right habitat and suitable environmental factors that influence the success of edible bird nest production in Malaysia. *Asian Journal of Agricultural Research*, *8*(1), 1–16.

Jacobs, R. D. (2015). Dietary supplementation of omega-3 fatty acids influences the equine maternal uterine environment and embryonic development. *Doctoral Dissertations. Virginia Polytechnic Institute and State University*, 136.

Jong, C. H., Tay, K. M., & Lim, C. P. (2013). Application of the fuzzy Failure Mode and Effect Analysis methodology to edible bird nest processing. *Computers and Electronics in Agriculture*, *96*(8), 90–108.

Juan, L. W., Liao, C. C., Lai, W. S., Chang, C. Y., Pei, J. C., Wong, W. R., … Lee, L. J. (2014). Phenotypic characterization of C57BL/6J mice carrying the Disc1 gene from the 129S6/SvEv strain. *Brain Structure and Function*, *219*(4), 1417–1431.

Kanato, Y., Kitajima, K., & Sato, C. (2008). Direct binding of polysialic acid to a brain-derived neurotrophic factor depends on the degree of polymerization. *Glycobiology*, *18*(12), 1044–1053.

Kang, N., Hails, C. J., & Sigurdsson, J. B. (1991). Nest construction and egg- laying in edible- nest swiftlets *Aerodramus spp*. and the implications for harvesting.

Ibis, *133*(2), 170–177.

Karim, M., & Wang, B. (2006). Is sialic acid in milk food for the brain? *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *1*(018), 1–11.

Karnebeek, C. D. M. Van, Bonafé, L., Wen, X. Y., Tarailo-Graovac, M., Balzano, S., Royer-Bertrand, B., … Superti-Furga, A. (2016). NANS-mediated synthesis of sialic acid is required for brain and skeletal development. *Nature Genetics*, *48*(7), 777–784.

Kathan, R. H., & Weeks, D. I. (1969). Structure studies of collocalia mucoid. I. Carbohydrate and amino acid composition. *Archives of Biochemistry and Biophysics*, *134*(2), 572–576.

Kenser, R. P., Lee, I., & Paul Gilbert. (2004). A behavioral assessment of hippocampal function based on a subregional analysis. *Journal of Neuronsciens*, *15*(5), 333–351.

Keum, S., Park, J., Kim, A., Park, J., Kim, K. K., Jeong, J., & Shin, H. S. (2016). Variability in empathic fear response among 11 inbred strains of mice. *Genes, Brain and Behavior*, *15*(2), 231–242.

Kim, K. C., Kang, K. A., Lim, C. M., Park, J. H., Jung, K. S., & Hyun, J. W. (2012). Water extract of edible bird's nest attenuated the oxidative stress-induced matrix metalloproteinase-1 by regulating the mitogen-activated protein kinase and activator protein-1 pathway in human keratinocytes. *Journal of the Korean Society for Applied Biological Chemistry*, *55*(3), 347–354.

Kitajka, K., Sinclair, A. J., Weisinger, R. S., Weisinger, H. S., Mathai, M., Jayasooriya, A. P., … Puskas, L. G. (2004). Effects of dietary omega-3 polyunsaturated fatty acids on brain gene expression. *Proceedings of the National Academy of Sciences*, *101*(30), 10931–10936.

Koike, M., Shibata, M., Tadakoshi, M., Gotoh, K., Komatsu, M., Waguri, S., … Uchiyama, Y. (2008). Inhibition of Autophagy Prevents Hippocampal Pyramidal Neuron Death after Hypoxic-Ischemic Injury. *The American Journal of Pathology*, *172*(2), 454–469.

Kowiański, P., Lietzau, G., Czuba, E., Waśkow, M., Steliga, A., & Moryś, J. (2018). BDNF: a key factor with multipotent impact on brain signaling and synaptic plasticity. *Cellular and Molecular Neurobiology*, *38*(3), 579–593.

Kraeuter, A. K., Guest, P. C., & Sarnyai, Z. (2019). The Y-maze for assessment of spatial working and reference memory in mice. *Methods in Molecular Biology* Vol. 10.

Krueger, K., Farmer, K., & Heinze, J. (2014). The effects of age, rank and neophobia on social learning in horses. *Animal Cognition*, *17*(3), 645–655.

Krueger, K., & Heinze, J. (2008). Horse sense: social status of horses (*Equus caballus*) affects their likelihood of copying other horses' behavior. *Animal Cognition*, *11*(3), 431–439.

Kurosawa, N., Yoshida, Y., Kojima, N., & Tsuji, S. (1997). Polysialic acid synthase (ST8Sia II/STX) mRNA expression in the developing mouse central nervous system. *Journal of Neurochemistry*, *69*(2), 494–503.

Laugero, K. D., Adkins, Y., Mackey, B. E., & Kelley, D. S. (2017). Emotion-based cognition in mice is differentially influenced by dose and chemical form of dietary docosahexaenoic acid. *Nutrients*, *9*(9), 993.

Lee, J., Duan, W., Long, J. M., Ingram, D. K., & Mattson, M. P. (2000). Dietary restriction increases the number of newly generated neural cells, and BDNF expression, in the dentate gyrus of rats. *Journal of Molecular Neuroscience*, *15*(2), 99–108. https://doi.org/10.1385/JMN:15:2:99

Lee, T. H., Wani, W. A., Koay, Y. S., Kavita, S., Tan, E. T. T., & Shreaz, S. (2017). Recent advances in the identification and authentication methods of edible bird's nest. *Food Research International*, *100*, 14–27.

Lei Jiang, Bechtel, M. D., Bean, J. L., Winefield, R., Williams, T. D., Zaidi, A., … Michaelis, M. L. (2014). Effects of gangliosides on the activity of the plasma membrane Ca2+-ATPase. *Biochim Biophys Acta*, *1838*(5), 1255–1265.

Li, Q., Wang, M., & Gu, W. (2002). Computer vision based system for apple surface defect detection. *Computers and Electronics in Agriculture*, *36*(2–3), 215–223.

Li, Y., & Chen, X. (2012). Sialic acid metabolism and sialyltransferases: natural functions and applications. *Applied Microbiology and Biotechnology*, *94*(4), 887–905.

Linh, T. T. M., Son, H. Le, & Ai, H. M. M. (2019). Nutritional content of vietnamese edible bird's nest from selected regions. *European Journal of Nutrition & Food Safety*, *9*(1), 66–71.

Linnarsson, S., Willson, C. A., & Ernfors, P. (2000). Cell death in regenerating populations of neurons in BDNF mutant mice. *Molecular Brain Research*, *75*(1), 61–69.

Lundberg, J., & McFarlane, D. A. (2012). National transformation programme (NTP) annual report 2017. *Geomorphology*, *157–158*, 153–168.

Ma, F., & Liu, D. (2012). Sketch of the edible bird's nest and its important bioactivities. *Food Research International*, *48*(2), 559–567.

Ma, X., Zhang, J., Liang, J., & Chen, Y. (2020). Element analysis of house-and cave-ebn (Edible bird's nest) traceability by inductively coupled plasma-mass spectrometry (ICP-MS) integrated with chemo-metrics. *Materials Express*, *10*(7), 1141–1148.

Ma, Y., Tian, S., Wang, Z., Wang, C., Chen, X., Li, W., … He, S. (2016). CMP-N-acetylneuraminic acid synthetase interacts with fragile X related protein 1. *Molecular Medicine Reports*, *14*(2), 1501–1508.

Mandolesi, L., Gelfo, F., Serra, L., Montuori, S., Polverino, A., Curcio, G., & Sorrentino, G. (2017). Environmental factors promoting neural plasticity: Insights from animal and human studies. *Neural Plasticity*, *2017*(6), 1–10.

Marcone, M. F. (2005). Characterization of the edible bird's nest the "Caviar of the East." *Food Research International*, *38*(10), 1125–1134.

Marni, S., Marzura, M. R., Norzela, A. M., Khairunnisak, M., Bing, C. H., & Eddy, A. A. (2014). Preliminary study on free sialic acid content of edible bird nest from Johor and Kelantan. *Malaysian Journal of Veterinary Research*, *5*(1), 9–14.

Marty, S. (2000). Differences in the regulation of neuropeptide Y, somatostatin and parvalbumin levels in hippocampal interneurons by neuronal activity and BDNF. *Progress in Brain Research*, *128*, 193–202.

Matsukawa, N., Matsumoto, M., Bukawa, W., Chiji, H., Nakayama, K., Hara, H., & Tsukahara, T. (2011). Improvement of bone strength and dermal thickness due to dietary edible bird's nest extract in ovariectomized rats. *Bioscience, Biotechnology, and Biochemistry*, *75*(3), 590–592.

Medway, Lord. (1962). the relation between the reproductive cycle, moult and changes in the sublingual salivary glands of the swiftlet *Collocalia maxima Kijme*. *Proceedings of the Zoological Society of London*, *138*(2), 305–315.

Mehta, M., & Schmauss, C. (2011). Strain-specific cognitive deficits in adult mice exposed to early life stress. *Behavioral Neuroscience*, *125*(1), 29–36.

Morgan, B. L. G., & Winick, M. (1981). The subcellular localization of administered N-acetylneuraminic acid in the brains of well-fed and protein restricted rats. *British Journal of Nutrition*, *46*(2), 231–238.

Mori, A., Hane, M., Niimi, Y., Kitajima, K., & Sato, C. (2017). Different properties of polysialic acids synthesized by the polysialyltransferases ST8SIA2 and ST8SIA4. *Glycobiology*, *27*(9), 834–846.

Nabilah, N., Mohamad, H., & Nawi, N. M. (2018). Consumer ' s perception on the quality of controversial contents in edible bird ' s nest products. *Scholarly Research Reviews*, *4*, 1–9.

Nishino, I., Carrillo-Carrasco, N., & Argov, Z. (2015). GNE myopathy: Current update and future therapy. *Journal of Neurology, Neurosurgery and Psychiatry*, *86*(4), 385–392.

Norhayati, M. K., Azman, O., & Wan Nazaimoon, W. M. (2010). Preliminary study of the nutritional content of Malaysian edible bird's nest. *Malaysian Journal*

of Nutrition, *16*(3), 389–396.

Nurul Huda, M. Z., Zuki, A. B. Z., Azhar, K., Goh, Y. M., Suhaimi, H., Hazmi, A. J. A., & Zairi, M. S. (2008). Proximate, elemental and fatty acid analysis of pre-processed edible birds' nest *(Aerodramus fuciphagus)*: a comparison between regions and type of nest. *Journal of Foiod Technology*, *6*(6), 39–44.

Obelitz-Ryom, K., Bering, S. B., Overgaard, S. H., Eskildsen, S. F., Ringgaard, S., Olesen, J. L., … Thymann, T. (2019). *Bovine* milk oligosaccharides with sialyllactose improves cognition in preterm pigs. *Nutrients*, *11*(6), 1335.

Oghenesuvwe, E. E., Nwoke, E., & Lotanna, A. D. (2014). Guidelines on dosage calculation and stock solution preparation in experimental animal s ' studies. *Journal of Natural Sciences Research*, *4*(18), 100–106.

Oliveros, E., Vázquez, E., Barranco, A., Ramírez, M., Gruart, A., Delgado-García, J. M., … Martín, M. J. (2018). Sialic acid and sialylated oligosaccharide supplementation during lactation improves learning and memory in rats. *Nutrients*, *10*(10), 1–16.

Ou, K., Seow, T. K., Liang, R. C. M. Y., Lee, B. W., Goh, D. L. M., Chua, K. Y., & Chung, M. C. M. (2001). Identification of a serine protease inhibitor homologue in Bird's Nest by an integrated proteomics approach. *Electrophoresis*, *22*(16), 3589–3595.

Paccalet, T., Coulombe, Z., & Tremblay, J. P. (2010). Ganglioside GM3 levels are altered in a mouse model of HIBM: GM3 as a cellular marker of the disease. *PLoS One*, *5*(4), 1–7.

Palmano, K., Rowan, A., Guillermo, R., Guan, J., & McJarrow, P. (2015). The role of gangliosides in neurodevelopment. *Nutrients*, *7*(5), 3891–3913.

Palumbo, A. L., Zubilete, A. A. Z., Cremaschi, G. A., & Mari, A. N. A. (2009). Different effect of chronic stress on learning and memory in BALB / c and C57BL / 6 inbred mice : Involvement of hippocampal NO production and PKC activity, *Stress*, *12*(7), 350–361.

Pencea, V., Bingaman, K. D., Wiegand, S. J., & Luskin, M. B. (2001). Infusion of brain-derived neurotrophic factor into the lateral ventricle of the adult rat leads to new neurons in the parenchyma of the striatum, septum, thalamus, and hypothalamus. *Journal of Neuroscience*, *21*(17), 6706–6717.

Plomp, J. J., & Willison, H. J. (2009). Pathophysiological actions of neuropathy-related anti-ganglioside antibodies at the neuromuscular junction. *Journal of Physiology*, *587*(16), 3979–3999.

Praag, V., Af, S., Br, C., N, T., Td, P., & Fh, G. (2002). Functional neurogenesis in the adult hippocampus. *Nature*, *415*(2), 1030–1034.

Price, J. J., Johson, K. P., Bush, S. E., & Clayton, D. H. (2005). Phylogenetic relationships of the Papuan Swiftlet *Aerodramus papuensis* and implications for the evolution of avian echolocation. *Ibis*, *147*(4), 790–796.

Qiao, Y., Feng, J., Yang, J., & Gu, G. (2013). The relationship between dietary vitamin A intake and the levels of sialic acid in the breast milk of lactating women. *Journal of Nutritional Science and Vitaminology*, *59*(4), 347–351.

Quek, M. C., Chin, N. L., Yusof, Y. A., Law, C. L., & Tan, S. W. (2018a). Characterization of edible bird's nest of different production, species and geographical origins using nutritional composition, physicochemical properties and antioxidant activities. *Food Research International*, *109*, 35–45.

Quek, M. C., Chin, N. L., Yusof, Y. A., Law, C. L., & Tan, S. W. (2018b). Pattern recognition analysis on nutritional profile and chemical composition of edible bird's nest for its origin and authentication. *International Journal of Food Properties*, *21*(1), 1680–1696.

Quek, M. C., Chin, N. L., Yusof, Y. A., Tan, S. W., & Law, C. L. (2015). Preliminary nitrite, nitrate and colour analysis of Malaysian edible bird's nest. *Information Processing in Agriculture*, *2*(1), 1–5.

Ramlan, M., Ideris, A., & Abu, J. (2018). An overview of research and industry connectivity. *Malaysian Journal of Veterinary Research*, *9*(1), 81–90.

Rashed, A. A., & Nazaimoon, W. W. M. (2010). Effect of edible bird's nest on Caco-2 cell proliferation. *Journal of Food Technology*, *8*(3), 126–130.

Report, A. (2014). Annual report performance management and delivery unit (PEMANDU) Contents. Retrieved from www.pemandu.gov.my

Roberson, D. (2012). Swifts: A guide to the swifts and treeswifts of the world Phil Chantler. *The Auk*, *118*(1), 274–277.

Roh, K. B., Lee, J., Kim, Y. S., Park, J., Kim, J. H., Lee, J., & Park, D. (2012). Mechanisms of edible bird's nest extract-induced proliferation of human adipose-derived stem cells. *Evidence-Based Complementary and Alternative Medicine*, *2012*, 1-11.

Rutishauser, U. (2008). Polysialic acid in the plasticity of the developing and adult vertebrate nervous system. *Nature Reviews Neuroscience*, *9*(1), 26–35.

Ryan, J. M., Rice, G. E., & Mitchell, M. D. (2013). The role of gangliosides in brain development and the potential benefits of perinatal supplementation. *Nutrition Research*, *33*(11), 877–887.

Saad, F. S. A., Ibrahim, M. F., Shakaff, A. Y. M., & Zakaria, A. (2015). Edible bird nest shape inspection using Fourier Descriptor (FD) and Farthest Fourier Point Signature (FFPS) method. *Jurnal Teknologi*, *76*(12), 17–24.

Saengkrajang, W., Matan, N., & Matan, N. (2011). Antimicrobial activities of the edible bird's nest exctracts agaist food-borne pathogens. *Journal of Agriculture Science*, *44*(5), 326–330.

Saengkrajang, Warasri, Matan, N., & Matan, N. (2013). Nutritional composition of the farmed edible bird's nest (*Collocalia fuciphaga*) in Thailand. *Journal of Food Composition and Analysis*, *31*(1), 41–45.

Salim, N. A. A., Othman, Z., Harun, N. A., Moosa, S., Omar, S. A., Azman, M. A., … Lim, C. C. (2018). A preliminarily study of elemental characterization for geochemical markers of house and cave edible bird's nest using NAA technique. *Jurnal Sains Nuklear Malaysia*, *30*(1), 30–35.

Sara J. Shettleworth. (2001). Animal cognition and animal behaviour. *Animal Behaviour*, *61*(2), 277–286.

Sato, C. (2017). Releasing mechanism of neurotrophic factors via polysialic acid. *Vitamins and Hormones*. Vol. 104, pp. 89–112.

Sato, Chihiro, & Kitajima, K. (2013). Disialic, oligosialic and polysialic acids: distribution, functions and related disease. *Journal of Biochemistry*, *154*(2), 115–136.

Savage, J. E., Jansen, P. R., Stringer, S., Watanabe, K., Bryois, J., De Leeuw, C. A., … Posthuma, D. (2018). Genome-wide association meta-analysis in 269,867 individuals identifies new genetic and functional links to intelligence. *Nature Genetics*, *50*(7), 912–919.

Scharfman, H. E. (1997). Hyperexcitability in combined entorhinal/hippocampal slices of adult rat after exposure to brain-derived neurotrophic factor. *Journal of Neurophysiology*, *78*(2), 1082–1095.

Scharfman, H., Goodman, J., Macleod, A., Phani, S., Antonelli, C., & Croll, S. (2005). Increased neurogenesis and the ectopic granule cells after intrahippocampal BDNF infusion in adult rats. *Experimental Neurology*, *192*(2), 348–356.

Schauer, R. (2000). Achievements and challenges of sialic acid research. *Glycoconjugate Journal*, *17*(7–9), 485–499.

Schuetz, A., Farmer, K., & Krueger, K. (2017). Social learning across species: horses (Equus caballus) learn from humans by observation. *Animal Cognition*, *20*(3), 567–573.

Seow, E. K., Ibrahim, B., Muhammad, S. A., Lee, L. H., & Cheng, L. H. (2016). Differentiation between house and cave edible bird's nests by chemometric analysis of amino acid composition data. *LWT - Food Science and Technology*, *65*, 428–435.

Shah, P., Bassett, D. S., Wisse, L. E. M., Detre, J. A., Stein, J. M., Yushkevich, P. A., … Das, S. R. (2018). Mapping the structural and functional network

architecture of the medial temporal lobe using 7T MRI. *Human Brain Mapping*, *39*(2), 851–865.

Shettleworth, S. J. (2010). Cognition, evolution, and behavior (2nd edi). *Oxford uniersity press*.

Sims, R. W. (2008). The identification of malaysian species of swiftlets *Collocalia*. *Ibis*, *103a*(2), 205–210.

Sipione, S., Monyror, J., Galleguillos, D., Steinberg, N., & Kadam, V. (2020). Gangliosides in the brain: physiology, pathophysiology and therapeutic applications. *Frontiers in Neuroscience*, *14*(10), 1–24.

Somm, E., Larvaron, P., van de Looij, Y., Toulotte, A., Chatagner, A., Faure, M., … Hüppi, P. S. (2014). Protective effects of maternal nutritional supplementation with lactoferrin on growth and brain metabolism. *Pediatric Research*, *75*(1), 51–61.

Sopian, N. F. A., Ajat, M., Shafie, N. I., Noor, M. H. M., Ebrahimi, M., Rajion, M. A., … Ahmad, H. (2015). Does short-term dietary omega-3 fatty acid supplementation influence brain hippocampus gene expression of zinc transporter-3? *International Journal of Molecular Sciences*, *16*(7), 15800–15810.

Spencer, S. J., Korosi, A., Layé, S., Shukitt-Hale, B., & Barrientos, R. M. (2017). Food for thought: how nutrition impacts cognition and emotion. *Nature Print Journal Science of Food*, *1*(1), 7.

Sprenger, N., & Duncan, P. I. (2012). Sialic acid utilization. *Advances in Nutrition*, *3*(3), 392S-397S.

Sprenger, N., Julita, M., Donnicola, D., & Jann, A. (2009). Sialic acid feeding aged rats rejuvenates stimulated salivation and colon enteric neuron chemotypes. *Glycobiology*, *19*(12), 1492–1502.

Stangl, D., & Thuret, S. (2009). Impact of diet on adult hippocampal neurogenesis. *Genes and Nutrition*, *4*(4), 271–282.

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*, *8*(3), 448–460.

Subramaniama, Y., Faib, Y. C., & Ming, E. S. L. (2015). Edible bird nest processing using machine vision and robotic arm. *Jurnal Teknologi*, *72*(2), 85–88.

Svennerholm, L., Boström, K., Fredman, P., Månsson, J. E., Rosengren, B., & Rynmark, B. M. (1989). Human brain gangliosides: developmental changes from early fetal stage to advanced age. *Biochimica et Biophysica Acta (BBA)/Lipids and Lipid Metabolism*, *1005*(2), 109–117.

Syahir, F. A. S., Shakaff, A. Y. M., Zakaria, A., Abdullah, M. Z., Adom, A. H., & Ezanuddin, A. A. M. (2012). Edible bird nest shape quality assessment using machine vision system. *Proceedings - 3rd International Conference on Intelligent Systems Modelling and Simulation, ISMS 2012*, 325–329.

Sydow, A., Van der Jeugd, A., Zheng, F., Ahmed, T., Balschun, D., Petrova, O., … Mandelkow, E.-M. (2011). Tau-induced defects in synaptic plasticity, learning, and memory are reversible in transgenic mice after switching off the toxic Tau mutant. *Journal of Neuroscience*, *31*(7), 2511–2525.

Taguchi, R., Minami, A., Matsuda, Y., Takahashi, T., Otsubo, T., Ikeda, K., & Suzuki, T. (2015). Preferential accumulation of 14C-N-glycolylneuraminic acid over 14C-N-acetylneuraminic acid in the rat brain after tail vein injection. *PLoS ONE*, *10*(6), 1–11.

Tai, S. K., Koh, R. Y., Ng, K. Y., & Chye, S. M. (2017). A mini review on medicinal effects of edible bird's nest. *Letters in Health and Biological Sciences*, *2*(2), 1–3.

Taliaz, D., Stall, N., Dar, D. E., & Zangen, A. (2010). Knockdown of brain-derived neurotrophic factor in specific brain sites precipitates behaviors associated with depression and reduces neurogenesis. *Molecular psychiatry*, *15*(1), 80-92.

Tan, S. N., Sani, D., Lim, C. W., Ideris, A., Stanslas, J., & Lim, C. T. S. (2020). Proximate analysis and safety profile of farmed edible bird's nest in malaysia and its effect on cancer cells. *Evidence-Based Complementary and Alternative Medicine*, *2020*, 1–12.

Tanila, H. (2018). Testing cognitive functions in rodent disease models : Present pitfalls and future perspectives. *Behavioural Brain Research*, *352*(4), 23–27.

Tanner, M. E. (2005). The enzymes of sialic acid biosynthesis. *Bioorganic Chemistry*, *33*(3), 216–228.

Tanti, A., & Belzung, C. (2013). Neurogenesis along the septo-temporal axis of the hippocampus: Are depression and the action of antidepressants region-specific? *Neuroscience*, *252*, 234–252.

Teh, Sue-Siang. Ma, Z.-F. (2018). Bioactive components and pharmacological properties of edible bird's nest. *International Proceedings of Chemical, Biological and Environmental Engineering*, *103*(7), 29–34.

Thavamanithevi, S., R. Sarifah, C.G. Lim, M. Theanmalar, M.S. Aidawati, M. D. D. and A. A. S. (2014). Characterization and standardization of edible birds nest (ebn)-determination of sialic acid Thavamanithevi,. *Proceedings of the Edible Bird Nest Industry Conference*, 25–26.

Transformation national annual programme. (2017). National transformation programme (NTP) annual report 2017, 208–209.

Traving, C., & Schauer, R. (1998). Structure, function and metabolism of sialic acids. *Cellular and Molecular Life Sciences*, *54*(12), 1330–1349.

Tung, C. H., Pan, J. Q., Chang, H. M., & Chou, S. S. (2008). Authentic determination of bird's nests by saccharides profile. *Journal of Food and Drug Analysis*, *16*(4), 86–91.

Tyng, C. M., Amin, H. U., Saad, M. N. M., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in Psychology*, *8*(AUG).

van Praag, H., Kempermann, G., & Gage, F. H. (2000). Neural consequences of enviromental enrichment. *Nature Reviews Neuroscience*, *1*(3), 191–198.

Venna, V. R., Deplanque, D., Allet, C., Belarbi, K., Hamdane, M., & Bordet, R. (2009). PUFA induce antidepressant-like effects in parallel to structural and molecular changes in the hippocampus. *Psychoneuroendocrinology*, *34*(2), 199–211.

Vimala, B., Hussain, H., & Nazaimoon, W. M. W. (2012). Effects of edible bird ' s nest on tumour necrosis factor-alpha secretion , nitric oxide production and cell viability of lipopolysaccharide-stimulated, *23*(4), 303–315.

Wainwright, P. E., & Colombo, J. (2006). Nutrition and the development of cognitive functions: interpretation of behavioral studies in animals and human infants. *The American Journal of Clinical Nutrition*, *84*(5), 961–970.

Wang, B., & Brand-Miller, J. (2003). The role and potential of sialic acid in human nutrition. *European Journal of Clinical Nutrition*, *57*(11), 1351–1369.

Wang, Bing. (2009). Sialic acid is an essential nutrient for brain development and cognition. *Annual Review of Nutrition*, *29*(1), 177–222.

Wang, Bing. (2012). Molecular mechanism underlying sialic acid as an essential nutrient for brain development and cognition. *Advances in Nutrition*, *3*(3), 465-472.

Wang, Bing, Brand-Miller, J., McVeagh, P., & Petocz, P. (2001). Concentration and distribution of sialic acid in human milk and infant formulas. *American Journal of Clinical Nutrition*, *74*(4), 510–515.

Wang, Bing, Hu, H., & Yu, B. (2006). Molecular characterization of pig ST8Sia IV a critical gene for the formation of neural cell adhesion molecule and its response to sialic acid supplement in piglets. *Nutritional Neuroscience*, *9*(3–4), 147–154.

Wang, Bing, McVeagh, P., Petocz, P., & Brand-Miller, J. (2003). Brain ganglioside and glycoprotein sialic acid in breastfed compared with formula-fed infants.

The American Journal of Clinical Nutrition, *78*(5), 1024–1029.

Wang, Bing, Miller, J. B., McNeil, Y., & McVeagh, P. (1998). Sialic acid concentration of brain gangliosides: variation among eight mammalian species. *Comparative Biochemistry and Physiology. Part A, Molecular & Integrative Physiology*, *119*(1), 435–439.

Wang, Bing, Yu, B., Karim, M., Honghua, H., Sun, Y., Paul, M., … Brand-Miller, J. (2007). Dietary sialic acid supplementation improves learning and memory in piglets 1-3. *American Society for Nutrition*, *85*, 561–569.

Webster, S. J., Bachstetter, A. D., Nelson, P. T., Schmitt, F. A., & Van Eldik, L. J. (2014). Using mice to model Alzheimer's dementia: an overview of the clinical disease and the preclinical behavioral changes in 10 mouse models. *Frontiers in Genetics*, *5*(4), 1–23.

Wheeler, D. W., White, C. M., Rees, C. L., Komendantov, A. O., Hamilton, D. J., & Ascoli, G. A. (2015). Hippocampome. org : a knowledge base of neuron types in the rodent hippocampus. *eLIFE Tools and resources*, 4, 1–28.

Wieruszeski, J. M., Michalski, J. C., Montreuil, J., Strecker, G., Peter-Katalinic, J., Egge, H., … Vliegenthart, J. F. (1987). Structure of the monosialyl oligosaccharides derived from salivary gland mucin glycoproteins of the Chinese swiftlet (*genus Collocalia*). Characterization of novel types of extended core structure, Gal beta(1–3)[GlcNAc beta(1–6)] GalNAc alpha(1–3). *Journal of Biological Chemistry*, *262*(14), 6650–6657.

Wolf, A., Bauer, B., Abner, E. L., Ashkenazy-Frolinger, T., & Hartz, A. M. S. (2016). A comprehensive behavioral test battery to assess learning and memory in 129s6/tg2576 mice. *PLOS ONE*, *11*(1), 1–23.

Wong, C. F., Chan, G. K. L., Zhang, M. L., Yao, P., Lin, H. Q., Dong, T. T. X., … Tsim, K. W. K. (2017). Characterization of edible bird's nest by peptide fingerprinting with principal component analysis. *Food Quality and Safety*, *1*(1), 83–92.

Wong, R. S. Y. (2013). Edible bird's nest: Food or medicine? *Chinese Journal of Integrative Medicine*, *19*(9), 643–649.

Wu, M. V., & Hen, R. (2014). Functional dissociation of adult-born neurons along the dorsoventral axis of the dentate gyrus. *Hippocampus*, *24*(7), 751–761.

Xie, Y., Zeng, H., Huang, Z., Xu, H., Fan, Q., Zhang, Y., & Zheng, B. (2018). Effect of maternal administration of edible bird's nest on the learning and memory abilities of suckling offspring in mice. *Neural Plasticity*, *2018*, 1–13.

Yamada, K., & Nabeshima, T. (2003). Current perspective brain-derived neurotrophic factor / TrkB signaling in memory processes. *J Pharmocol Sci*, *91*, 267–270.

Yew, M. Y., Koh, R. Y., Chye, S. M., Othman, I., & Ng, K. Y. (2014). Edible bird's nest ameliorates oxidative stress-induced apoptosis in SH-SY5Y human neuroblastoma cells. *BMC Complementary and Alternative Medicine*, *14*, 391.

Yew, M. Y., Koh, R. Y., Chye, S. M., Othman, I., Soga, T., Parhar, I., & Ng, K. Y. (2018). Edible bird's nest improves motor behavior and protects dopaminergic neuron against oxidative and nitrosative stress in Parkinson's disease mouse model. *Journal of Functional Foods*, *48*(July), 576–585.

Yew, M. Y., Koh, R. Y., Chye, S. M., Zainal Abidin, S. A., Othman, I., & Ng, K. Y. (2019). Neurotrophic properties and the de novo peptide sequencing of edible bird's nest extracts. *Food Bioscience*, *32*(9), 1–12.

Yida, Z., Imam, M. U., Ismail, M., Hou, Z., Abdullah, M. A., Ideris, A., & Ismail, N. (2015). Edible Bird's Nest attenuates high fat diet-induced oxidative stress and inflammation via regulation of hepatic antioxidant and inflammatory genes. *BMC Complementary and Alternative Medicine*, *15*(1), 1–7.

Yida, Z., Imam, M. U., Ismail, M., Ismail, N., & Hou, Z. (2015). Edible bird's nest attenuates procoagulation effects of high-fat diet in rats. *Drug Design, Development and Therapy*, *2015*(9), 3951–3959.

Yoshida, Y., Kojima, N., & Tsuji, S. (1995). Molecular cloning and characterization of a third type of N-glycan α2, 8-sialyltransferase from mouse lung1. *The Journal of Biochemistry*, *118*(3), 658–664.

Yu-Qin, Y., Liang, X., Hua, W., Hui-Xing, Z., Xin-Fang, Z., & Bu-Sen, L. (2000). Determination of edible bird's nest and its products by gas chromatography. *Journal of Chromatographic Science*, *38*(1), 27–32.

Zainal Abidin, F., Hui, C. K., Luan, N. S., Mohd Ramli, E. S., Hun, L. T., & Abd Ghafar, N. (2011). Effects of edible bird's nest (EBN) on cultured rabbit corneal keratocytes. *BMC Complementary and Alternative Medicine*, *11*(1), 94.

Zhang, Chao, Chen, J., Liu, Y., & Xu, D. (2019). Sialic acid metabolism as a potential therapeutic target of atherosclerosis. *Lipids in Health and Disease*, *18*(1), 1–11.

Zhang, Cheng, Li, Y., Wang, C., Lv, R., & Song, T. (2013). Extremely low-frequency magnetic exposure appears to have no effect on pathogenesis of alzheimer's disease in aluminum-overloaded rat. *PLoS ONE*, *8*(8), 1–8.

Zhao, C., Deng, W., & Gage, F. H. (2008). Mechanisms and functional implications of adult neurogenesis. *Cell*, *132*(4), 645–660.

Zhao, R., Li, G., Kong, X. J., Huang, X. Y., Li, W., Zeng, Y. Y., & Lai, X. P. (2016). The improvement effects of edible bird's nest on proliferation and activation of B lymphocyte and its antagonistic effects on immunosuppression induced by cyclophosphamide. *Drug Design, Development and Therapy*, *10*, 371–381.

Zerwas, M., Trouche, S., Richetin, K., Escudé, T., Halley, H., Gerardy-Schahn, R., ... & Rampon, C. (2016). Environmental enrichment rescues memory in mice deficient for the polysialytransferase ST8SiaIV. *Brain Structure and Function, 221*(3), 1591–1605.

Zhian, L., Gao, J., Wang, L., Chen, Z., Yuan, H., Ma, X., … Ma, L. (2016). Uremia-caused changes of ghrelin system in hippocampus may be associated with impaired cognitive function of hippocampus. *International Urology and Nephrology*, *48*(5), 807–815.

Zhiping, H., Imam, M. U., Ismail, M., Ismail, N., Yida, Z., Ideris, A., … Mahmud, R. (2015). Effects of edible bird's nest on hippocampal and cortical neurodegeneration in ovariectomized rats. *Food and Function*, *6*(5), 1701–1711.

APPENDICES

Appendix - 1

A: Nutritional composition of normal pellet given to the experimental animals

Composition	EBN-S	EBN-N	EBN-B	EBN-C	CTRL
Crude Protein	23.8	23.8	23.8	23.8	23.8
Crude Fibre	5.5	5.5	5.5	5.5	5.5
Crude Fat	5.0	5.0	5.0	5.0	5.0
Ash	9.8	9.8	9.8	9.8	9.8
Calcium	1.2	1.2	1.2	1.2	1.2
Phosphorus	0.9	0.9	0.9	0.9	0.9
Non-Protein Nitrogen	53.8	53.8	53.8	53.8	53.8
Total (DM)	100%	100%	100%	100%	100%
(As % Of Total Wet Weight) Moisture	13.0	13.0	13.0	13.0	13.0

B: Edible bird's nest extracts, diets and water provided for experimental animals

Composition	EBN-S	EBN-N	EBN-B	EBN-C	CTRL
EBN	10mg/kg (0.2 ml)	10mg/kg (0.2 ml)	10mg/kg (0.2 ml)	10mg/kg (0.2 ml)	-
Normal saline	-	-	-	-	0.2 ml
Normal pellet	ad libitum	ad libitum	ad libitum	ad libitum	ad libitum
Water	ad libitum	ad libitum	ad libitum	ad libitum	ad libitum

Appendix – 2

The sequential procedure of Haematoxylin and Eosin staining used for brain neuron morphological examination.

Haematoxylin and Eosin procedure		
Process	**Solution**	**Time (min)**
Deparaffinization	Xylene I	2 min
	Xylene II	2 min
Dehydration	100% alcohol	2 min
	90% alcohol	2 min
	70% alcohol	2 min
Wash	Running water	2 - 3 min
Staining	Haematoxylin	5 min
Wash	Running water	2 - 3 min
	Acid alcohol	3 dips
Wash	Running water	2-3 min
Staining	Eosin	5 min
Wash	Running water	2-3 min
Dehydration	70% alcohol	2-3 dips
	90% alcohol	2-3 dips
	100% alcohol	2-3 dips
	Xylene I	2-3 dips
	Xylene II	2-3 dips
Mounting	DPX	

Serology laboratory, Faculty of Veterinary Medicine, Universiti Putra Malaysia.

Appendix – 3

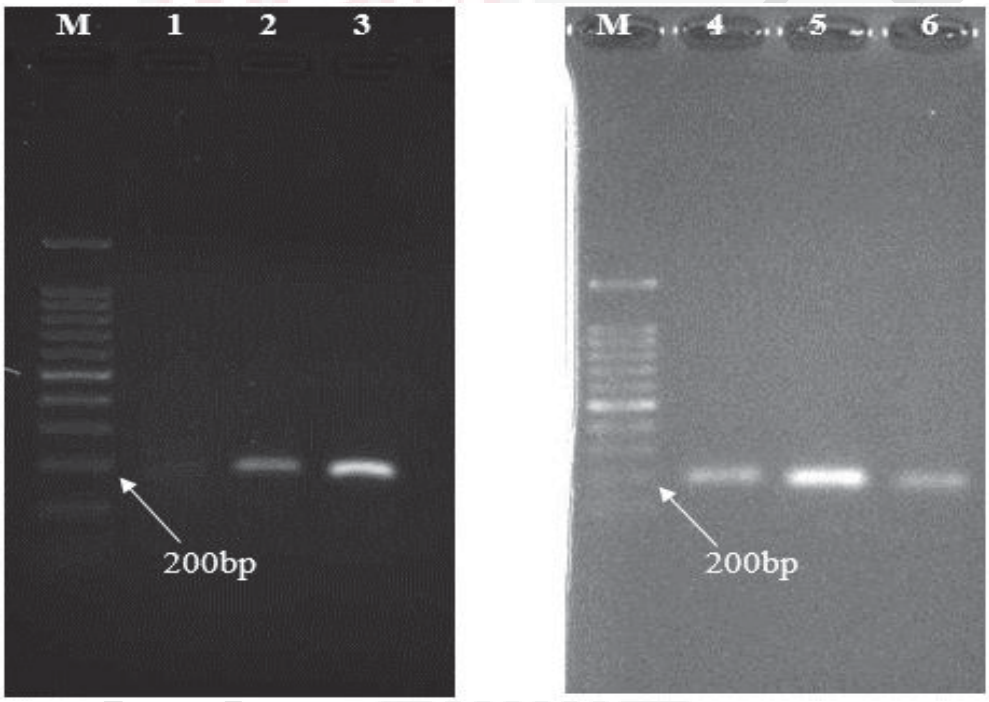
Brain hippocampal tissue samples of extracted mRNA from F0 and F1 generation animals used for reverse transcription to produce cDNA used in the qPCR.

Generation	No	Sample	Concentration (ng/µL)	A260/A280	A260/A230	Label for analysis
F0	1	EBN-S	488.6	2.07	2.19	F0S
	3	EBN-N	132.7	2.12	2.00	F0N
	2	EBN-B	786.9	2.09	2.18	F0B
	4	EBN-C	362.5	2.09	2.10	F0C
	5	CTRL	289.1	2.10	2.10	F0CTRL
F1	6	EBN-S	418.0	2.08	2.10	F1S
	8	EBN-N	576.3	2.05	2.02	F1N
	7	EBN-B	614.8	2.08	2.17	F1B
	9	EBN-C	332.3	2.10	2.18	F1C
	10	CTRL	662.1	2.07	1.96	F1CTRL

Appendix – 4

A: Size confirmation of the primers for the target and reference genes compared with the leader for RT-PCR.

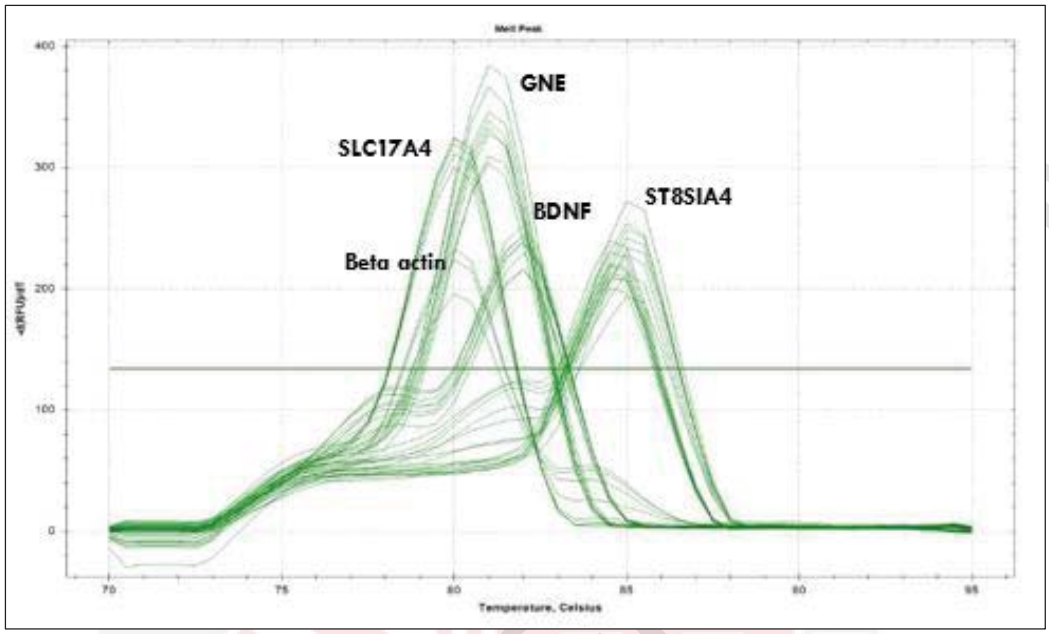
Number	Legend	Base pair
M	DNA Ladder	100bp
1	GAPDH	(176bp)
2	GNE	(188bp)
3	SLC17A5	(180bp)
4	Beta Actin	(186bp)
5	ST8SIAIV	(176bp)
6	BDNF	(183bp)



B: Size confirmation of the primers for the reference genes (1 and 4) and target genes (2, 3, 5 and 6) was identified comparing with the ladder (M).

Appendix – 5

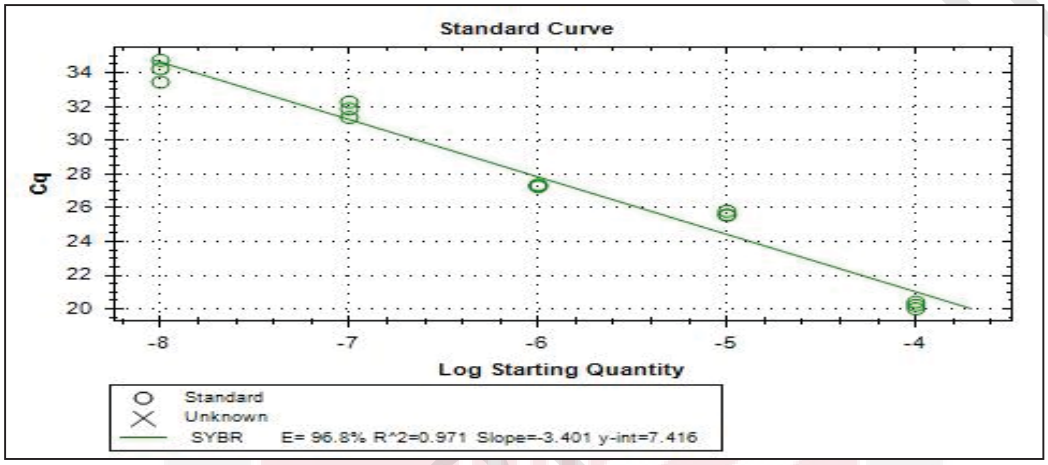
Annealing temperature optimization and the gradient annealing temperature for qPCR.



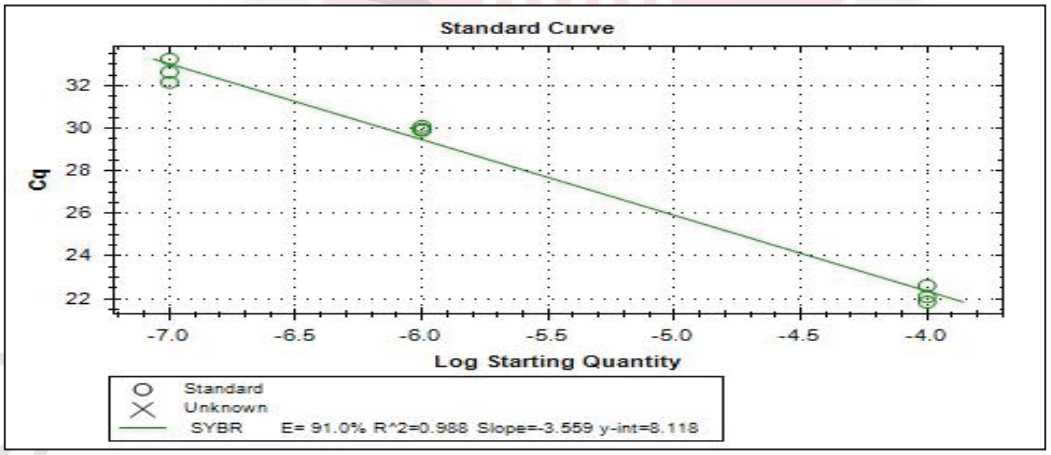
Appendix – 6

Efficiency of each target and reference gene using the serial dilution of cDNA prepared at 5-points tenfold dilution series starting from 100ng/µl to 0.01ng/µl.

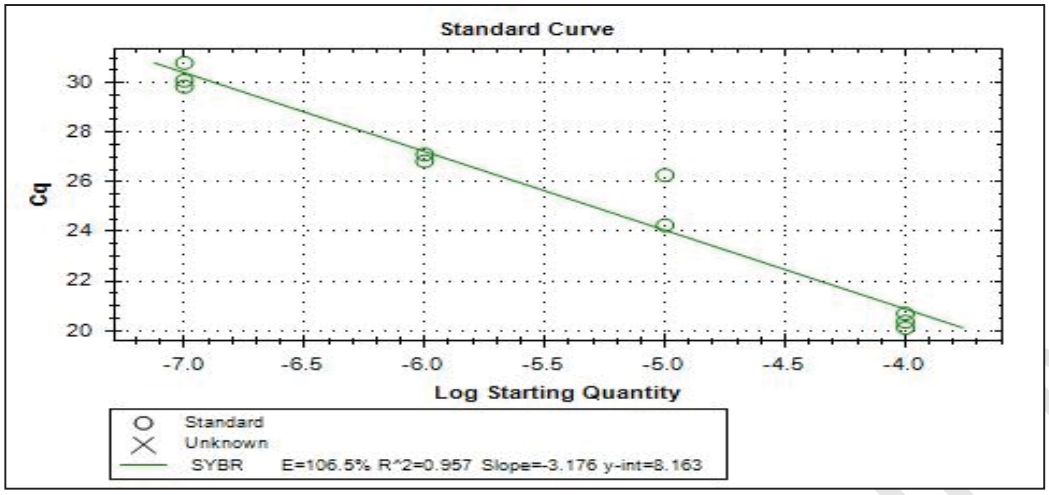
Primer	Efficiency (%) (90% - 110%)	Slope (-3.00 to -3.60)	R2 (>0.98)
Beta Actin	99.8	-3.328	0.996
ST8SIAIV	106.5	-3.176	0.957
GNE	91.0	-3.559	0.988
SLC17A5	100.00	-3.322	0.939
BDNF	96.8	-3.401	0.971



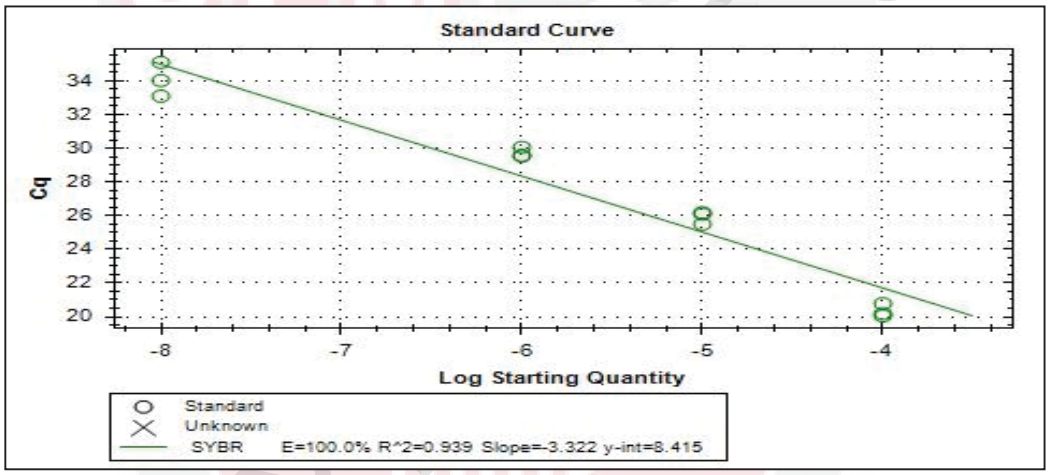
A: ***Beta Actin***



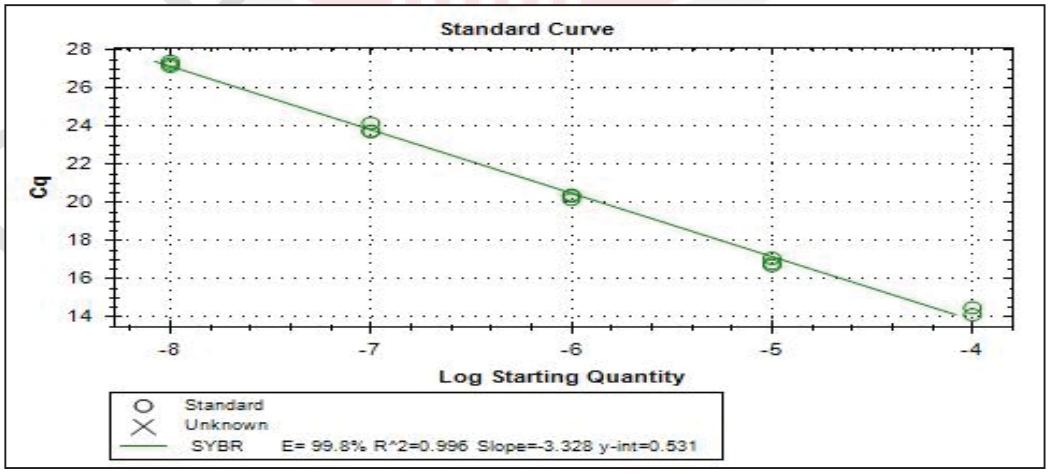
B: ***UDP-N-acetylglucosamine-2-epimerase/N- acetylmannosamine kinase (GNE)***



C: ***α-2,8-sialyltransferase IV (ST8SiaIV)***



D: ***Sialin (SLC17A5)***



E: ***Brain derived neurotrophic factor (BDNF)***

BIODATA OF STUDENT

Obaidullah Mahaq was born in Wardak Provence of Afghanistan on 15th April 1989. He lives in Afghanistan with his parents since then. He started his primary studies in Osmania Tangi primary School in 1995 and completed in 2001, while he continued his lower secondary and upper secondary studies in Emam Abo Hanifa High School until year 2007. He was enrolled for his Bachelor degree in Nangahar University of Afghanistan. He was graduated with a Bachelor degree in Doctor of Veterinary Medicine (DVM) in the year 2014. At the same year, he was appointed as an assistant lecturer in Faculty of Veterinary Medicine of Shaikh Zayed University Khost Afghanistan. After four years as assistant lecturer, he was offered a scholarship from Higher Education Development Program (HEDP) to continue his study in Animal Physiology at University Putra Malaysia (UPM), Malaysia. In UPM, he continued his Master of Veterinary Science with research interests in animal physiology specific on the brain cognitive function, neuro-histology and gene expression. During his Master study in UPM, he participated in various seminars, conferences and symposiums. He was completed several postgraduate subjects such as Molecular Physiology, Applied Animal Molecular Biology, Research Methodology and Advanced Research Methods with current cgpa 4.0

LIST OF PUBLICATIONS

Obaidullah Mahaq, Mohd Adha P. Rameli, Marilyn Jaoi Edward, Nursyuhaida Mohd Hanafi, Saleha Abdul Aziz, Hasliza Abu Hassim, Mohd Hezmee Mohd Noor and Hafandi Ahmad. (2020). The effects of dietary edible bird nest supplementation on learning and memory functions of multigenerational mice. *Brain and Behaviors*. *10*(11), 1–2 (published).

Obaidullah Mahaq, Mohd Adha P Rameli, Hasliza Abu Hassim, Mohd Hezmee Mohd Noor, Jalila Abu and Hafandi Ahmad (2019). Brain cellular changes of edible bird's nest supplementation on transgenerational mice. *Proceeding of Diversity in Veterinary Disease Investigation and Diagnosis.*

Obaidullah Mahaq, Mohd Adha P Rameli, Hasliza Abu Hassim, Mohd Hezmee Mohd Noor, Jalila Abu and Hafandi Ahmad (2019). Edible bird's nest supplementation improves neurons density and cognitive function of transgenerational mice. *Proceeding of Veterinary Association Malaysia.*

List of Seminars and Conferences

1. 11th Scientific Conference of Malaysian Association of Veterinary Pathology. Perdana Hotel, Kota Bharu Malaysia.26-28 July 2019. Title of presentation: "Brain cellular changes of edible bird's nest supplementation on transgenerational mice".

2. 31st Veterinary Association Malaysia Congress 2019. Bangi Resort Hotel Selangor Malaysia. 19-20 October 2019. Title of presentation: "Edible bird's nest supplementation improves neurons density and cognitive function of transgenerational mice".