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Postnatal Development of Endocrine Pancreatic Islets of an Egyptian One-humped Camel *(Camelus dromedarius)*

Ahmed Mohammed Rashwan[1,2*]

[1]Department of Anatomy and Embryology, Faculty of Veterinary Medicine, Damanhour University 22511, Egypt, [2]Department of Life Science Frontiers, Center for iPS Cell Research and Application, Kyoto University, Japan.

Abstract

This study aimed to ascertain the morphological and morphometric development of pancreatic islets as well as the average levels of numerous hormones during the postnatal development of camel pancreatic islets. Until recently, there has been no information on the aging development of pancreatic islets in the camel pancreas. In this study, three different ages (4 years, 8 years, and 18 years) were examined using histochemistry. The diameter of the camel pancreatic islet increased from 70.3 ± 1.5 µm in 4 years to 97 ± 1.6 µm in 18 years. The insulin cells were distributed all over the pancreatic islets, and their average increased from 65.7% in 4 years to 77.6% in 18-year-old camels. The glucagon cells were distributed in the periphery, and their percentage was around 11.2% in 4 years and 14.8% in 18 years. The somatostatin cells were distributed throughout the islets; their percentage was around 7.5% in 4 years and 9.4% in 18 years. This study examined the proliferation of pancreatic islets in order to comprehend the process that increases the size of pancreatic islets and insulin cells. There is no prior information describing the proliferation of beta cells in camel pancreatic islets. The proliferation was around 5.4% in insulin cells at 4 years and increased to 7.8% in insulin cells at 8 years. The current research clarifies that the size of pancreatic islets increases, and the percentage of insulin cells rise with aging, which is essential for maintaining blood glucose levels and aids camels in long-term adaptation to famine.

Keywords:

Camel, Glucagon, Insulin, Pancreas, Proliferation.

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*Corresponding Author: Ahmed Mohamed Rashwan E-mail: ahmed.rashwan@cira.kyoto-u.ac.jp

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Competing interest: The authors have declared that no competing interest exists.

Introduction

There are two types of camels: The one-humped camel, known as the Arabic camel or the dromedary camel, has spread across hot deserts in African countries, and this type is the most common in Egypt. The two-humped camel, also known as the Bactrian camel, or Camelus bactrianus, is found in Asia's cold deserts and dry plains (Abid Al-Redah and Hussin, 2016). Camels are subjected to harsh desert conditions such as a lack of water and nutrients, as well as hot weather (Gebreyohanes and Assen, 2017), so the camels have well-developed anatomical adaptations that aid in body temperature regulation and water conservation (Soliman, 2015).

The pancreas is composed of an endocrine and an exocrine gland that produce hormones as well as digestive enzymes (Stinson and Calhoun, 1981). The exocrine gland of the pancreas consists of many acinar glands, which transport digestive enzymes from the secretory acini to the intestine (Frappier, 2007). The endocrine system is made up of the aggregation of various cells, known as islets of Langerhans, which are dispersed among the exocrine cells and produce a variety of hormones (Gartner, 2006; Samuelson, 2007). The camel's pancreatic islets had a variety of shapes, including oval, round, and occasionally irregular (Sultan, 1999).

The pancreatic islets in the mammalian pancreas are composed of insulin-producing cells (β-cells), glucagon-producing cells (α-cells) and somatostatin-producing cells (Δ-cells) (Adeghate, 2001). The beta cells have a central location in the pancreatic islets in the majority of domestic mammals (Mukherjee et al., 1988; Sultan, 1999; Bargooth et al., 2020). However, the horse seemed to be the exception since the beta cells were located peripherally in the pancreatic islets (Furuoka et al., 1989; Hafez et al., 2015). In a variety of experimental species, including humans, beta-cell size rises quickly after birth due to proliferation, which is essential for beta-cell expansion (Cigliola et al., 2016; Bonner-Weir et al., 2016). Humans have more beta cells as a consequence of the proliferation (Dor et al., 2004).

Most animals had fewer alpha cells than beta cells, and they were located on the islet's periphery, with ovoid-shaped nuclei (Mukherjee et al., 1988). The horse seemed to be an exception since the alpha cells were located in the center of pancreatic islets (Furuoka et al., 1989). Most of the delta cells were located in the peripheral part of islets of pancreas in the camel (Alani, 1987), in bovines (Bonner-Wier and Like, 1980) and in the horse (Furuoka et al., 1989). The delta cells were located in the peripheral or central parts of pancreatic islets in camels (Khatim et al., 1985; Sultan, 1999).

Ki-67 has long been utilized as a proliferation marker in mammals and was discovered as an antigen in the cellular nucleus of Hodgkin lymphoma that is substantially expressed in cycling cells (Gerdes et al. 1984). Ki-67 undergoes cellular distribution variations, serves a variety of molecular functions, and plays various roles in both interphase and mitotic cell divisions (Sun and Kaufman, 2018). Because of this property, Ki-67 has become a clinically useful proliferation marker for a variety of mammals (Dowsett et al., 2011). Therefore, I consequently decided to use Ki-67 as a proliferative marker for beta cells in the camel pancreas.

The camel had a higher rate of tubular glucose reabsorption and a lower rate of glomerular filtration (Dahlborn et al., 1992; Khatim et al., 1985). But aside from this, nothing is understood about controlling blood sugar and how the endocrine

pancreas contributes to this phenomenon in camels. Only a few histological studies have been performed on the endocrine pancreas of adult one-humped camels (Adeghate, 1997; Tadjalli and Meamary, 1998; Hafez et al., 2015; Bargooth et al., 2020). But none of the previous studies described the postnatal development of pancreatic islets in camels.

The purpose of this study is to clarify the morphological and morphometric development of camel pancreatic islets in order to better understand the role of pancreatic islet hormones in assisting camels in surviving in the most hostile environments. Therefore, studying the postnatal development of the endocrine pancreas helps to elucidate the physiology underlying the camel's remarkable ability to survive for extended periods of time without water.

Materials and methods

Ethical standards:

All the study was conducted by following the National Institutes of Health Guidelines for the Care and Use of Laboratory Animals. The approval number of this investigation was (DMU/VetMed-2021-/0162) which was produced by the Ethics Animal Care Committee of Damanhour University in Egypt.

Animals and tissue preparation

Twenty Egyptian one-humped camel of different ages (4 years, 8 years, and 18 years; four camels for each age) were used in this study. Pancreas samples were taken soon after slaughter from healthy camels at the abattoir of the Kom Hamada in El-Behera, Egypt. Camel slaughter was done for human consumption, thus the slaughterhouse veterinarian checked camels before they were slaughtered to guarantee that camels could be consumed by humans and issued human consumption approval. As a result, all of pancreatic samples were normal and exhibited no pathological signs. For histological and immunohistochemical assessment, the specimen was promptly fixed in 4% paraformaldehyde dissolved in 0.1 phosphate-buffered saline (PBS) for 24 hours.

Light microscopic examination

The camel pancreas samples were dehydrated in ethyl alcohol grades ranging from 70% to 100%. The sample was cleared by using the histo-clear sample three times before paraffin impregnation in a hot oven using molten paraffin wax three times at 56 °C. Finally, blocks of the treated samples were made with paraffin wax and cut with a rotatory microtome. Thin (4-µm thick) paraffin sections were made from the block sample and mounted on glass slides that were coated with egg albumin-glycerin, then dried in an electrical incubator for 60 minutes at 45 °C, and then stained with Hematoxylin and eosin (H and E) as previously described by Bancroft and Layton (2013) for general inspection of pancreatic islets in one-humped camels.

Immunofluorescence examination:

Five different primary antibodies to understand the postnatal development of camel pancreatic islets. 4-µm thick paraffin sections were prepared, deparaffinized by histo-clear, rehydrated in descending grades of ethyl alcohol, and washed with distilled water. The first step was the antigen retrieval, which was done by adding slides into a solution of antigen retrieval (10 mM citrate buffer, low PH 6.0) and using an autoclave at 105 °C for 30 min, followed by PBS washing. The second step was the permeabilization, which was done using 0.2% Triton-PBS for 20 minutes. The third step was blocking the nonspecific reaction, which was done by using protein block

(Dako, Vector Laboratories, USA) and incubating for 30 min at room temperature. The fourth step was done by adding primary antibodies on slides and keeping them at 4 °C for overnight incubation (Table. 1). The fifth step was washing sections in PBS and incubating slides for 60 min with secondary antibodies (Table. 2).

Finally, the slides were mounted using Vectashield antifade mounting medium with DAPI (Vector Laboratories, USA). Images were captured using a fluorescence microscope, a BZ-9000E HS all-in-one microscope (Keyence).

Cell counting:

To count cells, 10 fields per section were randomly selected (from each 3 sections per animal) at x200 magnification and counted antibody-positive cells (n = 3 camel for each group).

Statistical analysis:

All statistical analyses were performed using GraphPad Prism 9 software, applying ordinary one-way ANOVA multiple comparison tests. P-values are described in Figure Legends.

All error bars in the figures represent the standard error of the mean.

Table 1. Primary antibodies used in the current study

Antibodies	Species	Dilution	Source, Catalogue no #
1. Insulin	Rabbit	1:400	Massachusetts, USA, Cat# CST,3014
2. Insulin	Mouse	1:1000	Chicago, IL, USA, ProteinTech, Cat# 66198-1-Ig
3. Glucagon	Mouse	1:800	Bornem, Belgium, Sigma, Cat# G2654
4. Somatostatin	Rabbit	1:400	Japan, Tokyo, Dako, Cat# A0566
5. Ki-67	Rabbit	1:1	Waltham, MA, USA, Thermo scientific, Cat# RM-9106

Table 2. Secondary antibodies used in the current study

Conjugate	Species	Antigen	Dilution	Supplier
1. Alexa fluor 488 (green)	Donkey	Rabbit IgG	1:500	Thermo Fisher Scientific Waltham, MA, USA
2. Alexa fluor 488 (red)	Donkey	Mouse IgG	1:500	Thermo Fisher Scientific Waltham, MA, USA
3. **Cyanine 3** (red)	Donkey	Mouse IgG	1:400	Merck Millipore Massachusetts, USA
4. Alexa fluor 647 (blue)	Donkey	Rabbit IgG	1:400	Merck Millipore Massachusetts, USA

Results

Postnatal development of camel pancreatic islet diameter

The current research investigates the postnatal development of camel pancreatic islets and evaluates the main variations in pancreatic islet characteristics, such as diameter of pancreatic islets, as well as providing explanations and recording the distribution area and average numbers of insulin, glucagon, and somatostatin at three different ages in camel pancreas.

The endocrine cells aggregate as clumps of cells, which are scattered within the pancreas of camels and known as Langerhans islets or pancreatic islets (Fig. 1A–C).

The pancreatic islets had different shapes, such as an oval shape, which is the most common shape, an elongated shape, and sometimes an irregular shape. The pancreatic islet cells had a paler appearance and could be recognized from the exocrine cells (pancreatic acini) (Fig. 1A–C). The pancreatic islet delineation was very thin, consisting of connective tissue that encircled and separated the pancreatic islets from the pancreatic acini of the camel pancreas (Fig. 1A-C).

The pancreatic islets increased in diameter with age in the camel pancreas (Fig. 2). I measured the diameter of camel pancreatic islets at three different ages (4, 8, and 18 years). The diameter of the pancreatic islet increased from 70.3 ± 1.5 µm in 4 years to 88.3 ± 2.5 µm in 8 years and finally reached 97 ± 1.6 µm in 18 years in the camel pancreas (Fig. 2). I checked the components of islets by observing different hormones to understand which hormone increased during postnatal development of the camel pancreas (Table. 3).

Postnatal development of camel pancreatic islet hormones

A variety of hormones were examined to see which ones increased in the camel pancreatic islets. The insulin cells were distributed all over the pancreatic islets in both the peripheral and central parts of the islets of Langerhans and (Fig. 3A-C).

The insulin cells had a round-shaped nucleus and were known as beta cells and expanded with age (Fig. 3A-C). The average number of insulin cells per islet increased with age in the camel pancreas,

with the number of insulin cells being 64 ± 1 cells/islet in 4 years and increasing to 78.6 ± 1.5 cells/islet in 8 years and 90.3 ± 2 cells/islet in 18 years (Fig. 4A). The insulin average was increased from 65.7% ± 1.8% in 4 years to 73% ± 1.9% in 8 years and 77.6% ± 2 in 18-year-old camels (Fig. 4B).

Glucagon cells were found on the periphery of pancreatic islets but not in the center (Fig. 5A-C). The glucagon cells had an oval-shaped nucleus and were known as alpha cells (Fig. 5A-C). The number of glucagon cells in the camel pancreas increased with age, starting at 11 ± 1 cells/islet at 4 years and increasing to 16 ± 1 cells/islet at 8 years and 17.3 ± 0.5 cells/islet at 18 years (Fig. 6A). The glucagon percentage was around 11.2% ± 0.6% in 4 years, 14.8% ± 0.7% in 8 years, and 14.8% ± 0.6% in 18 years (Fig. 6B). As a result, camels aged 8 years and older have essentially equal glucagon percentages (Table. 3).

The somatostatin cells were less abundant than insulin and glucagon and distributed throughout the islets (Fig. 7A-C). The number of somatostatin cells was increased in the camel pancreas from 7.3 ± 0.5 cells/islets in 4 years to 10 ± 1 cells/islets in 8 years and 11 ± 1 in 18 years (Fig. 8A). The somatostatin percentage was around 7.5% ± 0.5% in 4 years, 9.2% ± 0.7% in 8 years, and 9.4% ± 0.8% in 18 years (Fig. 8B). Therefore, a high increase in insulin cells was detected, but only a few increases in the cell numbers of glucagon and somatostatin were detected in one humped Egyptian camel (Table 3).

The difference in proliferation of pancreatic islets during the postnatal development of camel pancreatic islets

The beta-cell proliferation rate is detected by Ki-67 proliferative markers. The percentage of proliferating cells in beta-cells (insulin) in the camel pancreas increased from 4 to 8 years of age, then decreased in aged camels (Fig. 9A-C). The percentage of Ki-67 in positive insulin cells was 5.4% ± 1.2% in 4 years, increased to 7.8% ± 0.9% in 8 years and then stopped and decreased at old age, reaching 1.5% ± 0.5% (Fig. 10). Therefore, the increase in beta-cell proliferation has an important role in increasing pancreatic islet size (Table. 3

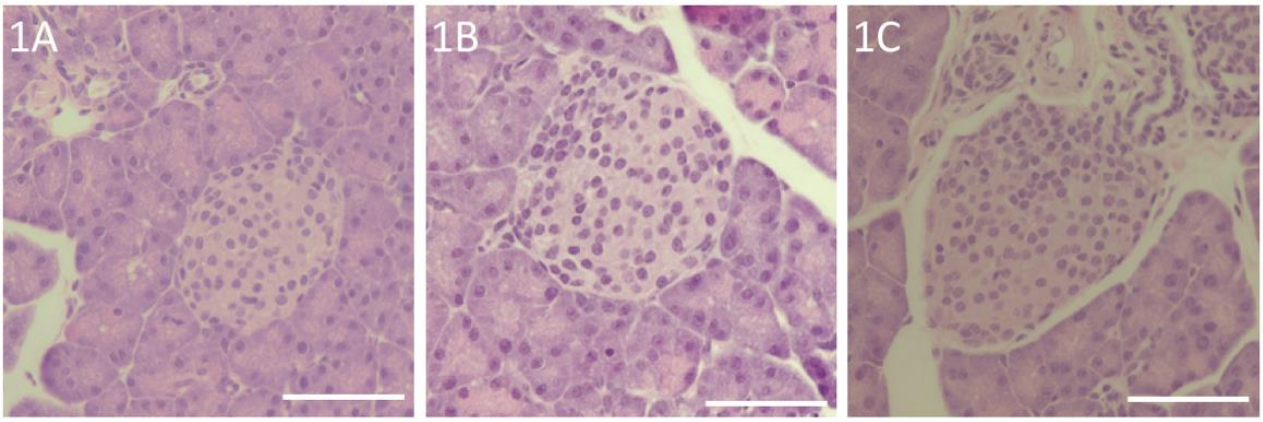

Fig. 1. Photomicrograph showing postnatal development of pancreatic islets diameter in camel pancreas by Haematoxylin and Eosin staining at 4 years (1A), 8 years (1B) and 18 years (1C). The diameter of the pancreatic islet in camel pancreas increased with age. Scale bar = 50 µm.

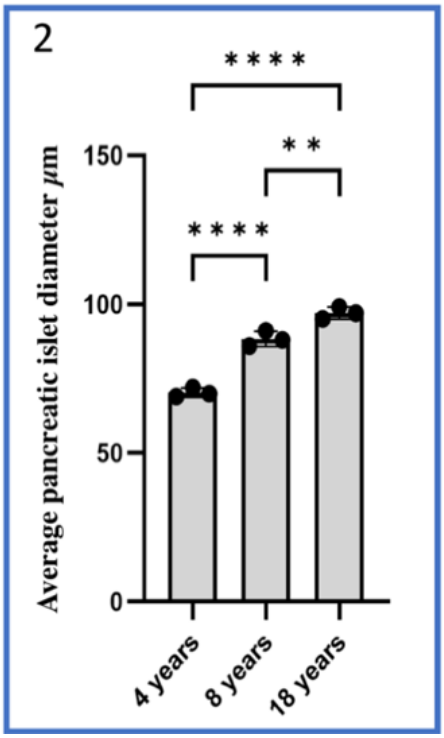

Fig. 2. Statistical analysis showing the difference in pancreatic islet diameter in camel pancreas at 3 different ages. Pancreatic islet diameter in camel pancreas increased with age. ** P < 0.01, **** P < 0.0001.

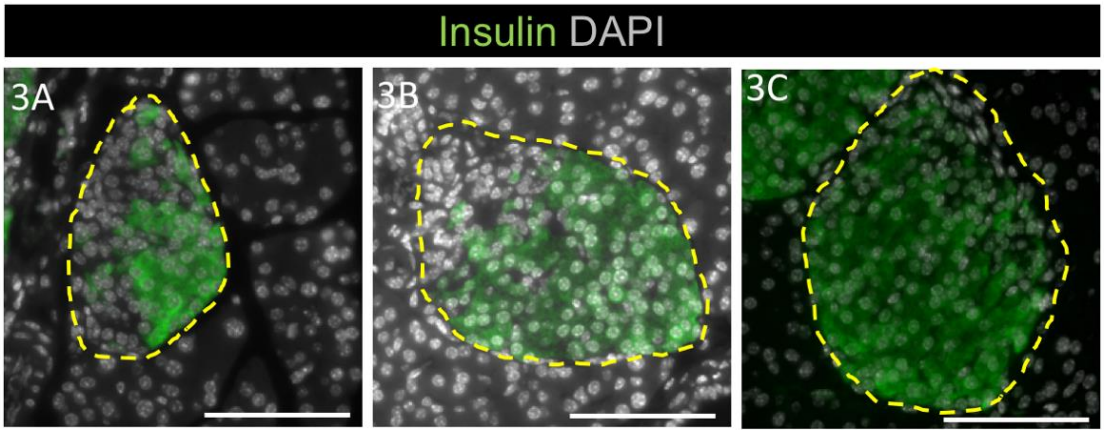

Fig. 3. Immunofluorescence expression of insulin (green), and 4′,6-diamidino-2-phenylindole, counterstaining of the nuclei (DAPI, white) at 4 years **(3A)**, 8 years **(3B)** and 18 years **(3C)**. Insulin increased with age and distributed in the center and periphery of pancreatic islets in camel pancreas. Scale bar = 50 µm.

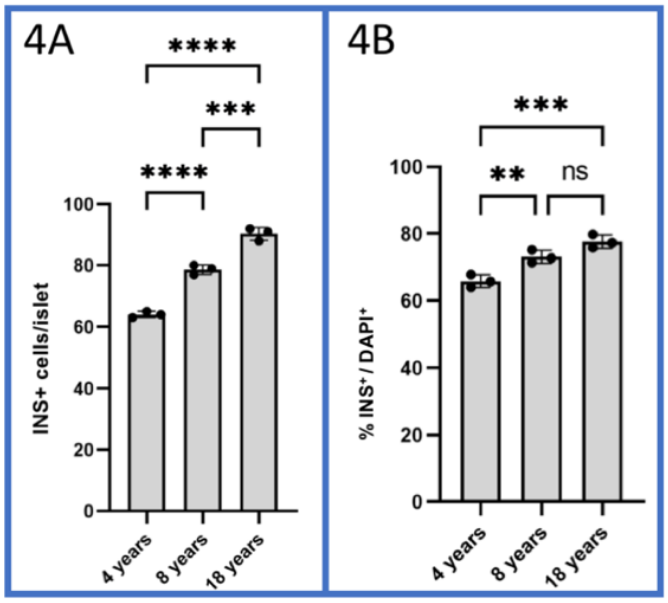

Fig. 4. Statistical analysis of the difference in the average cell number of pancreatic insulin **(4A)** and insulin hormone percentage (**4B)** in camel pancreas at 3 different ages. High increase in insulin cells number and percentage in camel pancreas with age. ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$, ns: not significant.

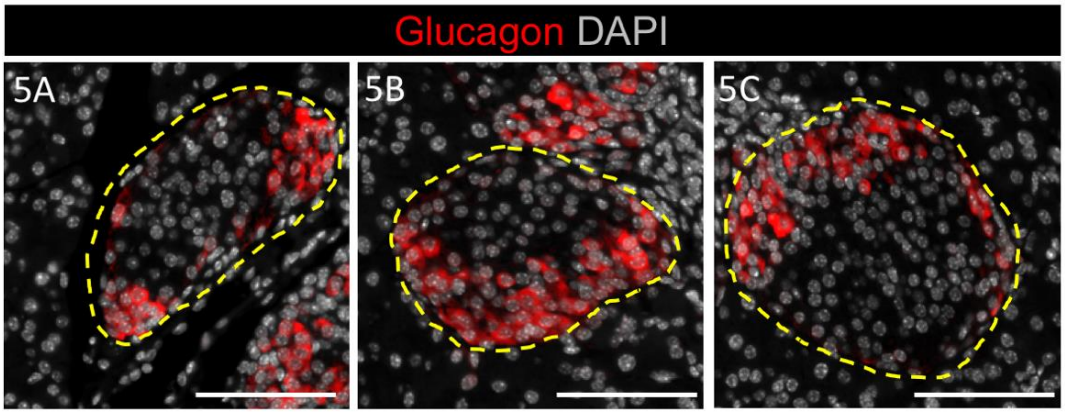

Fig. 5. Immunofluorescence expression of glucagon (red), and DAPI (white) at 4 years **(5A)**, 8 years **(5B)** and 18 years **(5C)**. Glucagon-expressing alpha cells are restricted in the periphery of the pancreatic islets in camel pancreas. Scale bar = 50 µm.

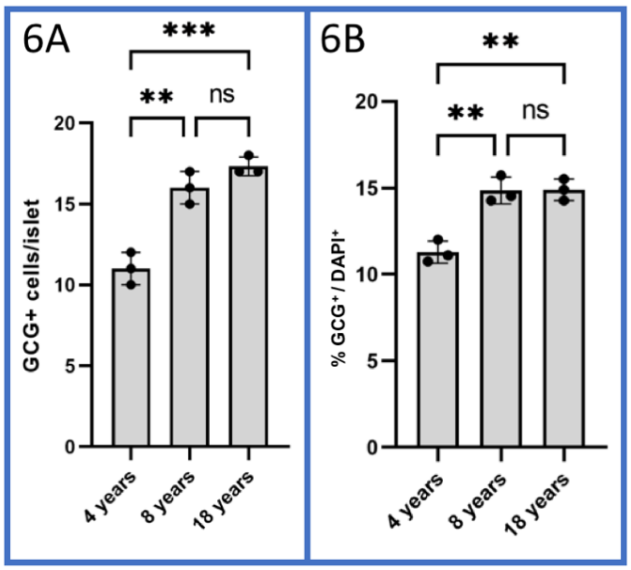

Fig. 6. Statistical analysis of the difference in the average cell number of pancreatic glucagon **(6A)** and glucagon hormone percentage **(6B)** in camel pancreas at three different age. Small increasing in glucagon cells number and percentage in camel pancreas with age and no difference between 8 years and 18 years. ** $P < 0.01$, *** $P < 0.001$, ns: not significant.

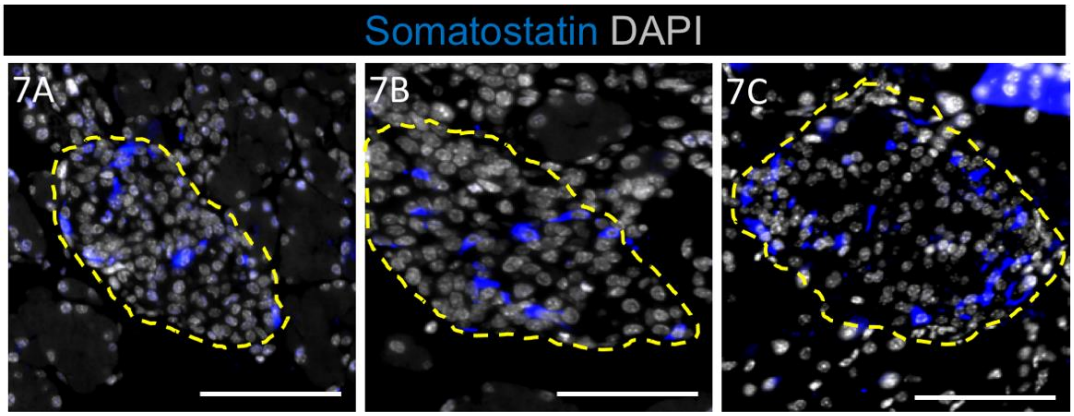

Fig. 7. Immunofluorescence expression of somatostatin (Blue), and DAPI (white) at 4 years **(7A)**, 8 years **(7B)** and 18 years **(7C)**. Many Somatostatin were scattered inside the pancreatic islet and not restricted in the peripheral in camel pancreatic islets. Scale bar = 50 µm.

Table 3. A summary of the postnatal development of camel pancreatic islets at 3 different ages

	Islet size µm	INS No / Islet	INS % / Islet	GCG No / Islet	GCG % / Islet	SST No / Islet	SST % / Islet	Ki-67 % / INS
4 Years	70.3 ± 1.5	64 ± 1	65.7% ± 1.8	11 ± 1	11.2% ± 0.6	7.3 ± 0.5	7.5% ± 0.5	5.4% ± 1.2
8 Years	88 ± 2.5	78.6 ± 1.5	73% ± 1.9	16 ± 1	14.8% ± 0.7	10 ± 1	9.2% ± 0.7	7.8% ± 0.9
18 Years	97 ± 1.6	90.3 ± 2	77.6 % ± 2	17.3 ± 0.5	14.8% ± 0.6	11 ± 1	9.4% ± 0.8	1.5% ± 0.5

INS, insulin; GCG, glucagon; SST, Somatostatin. The statistical analyses were performed using ordinary one-way ANOVA multiple comparison tests to assess the significant differences between three different ages. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$, NS: not significant. The significance of islet size was **** between 4 and 8 year, **** between 4 and 18 years and ** between

8 and 18 years. The significance of INS cells per islets was **** between 4 and 8 year, **** between 4 and 18 years and *** between 8 and 18 years. The significance of INS percentage was ** between 4 and 8 year, *** between 4 and 18 years and NS between 8 and 18 years. The significance of GCG cells per islets was ** between 4 and 8 year, *** between 4 and 18 years and NS between 8 and 18 years. The significance of GCG percentage was ** between 4 and 8 year, ** between 4 and 18 years and NS between 8 and 18 years. The significance of SST cells per islets was * between 4 and 8 year, ** between 4 and 18 years and NS between 8 and 18 years. The significance of SST percentage was NS between 4 and 8 year, * between 4 and 18 years and NS between 8 and 18 years. The significance of ki-67 percentage in INS was * between 4 and 8 year, ** between 4 and 18 years and *** between 8 and 18 years.

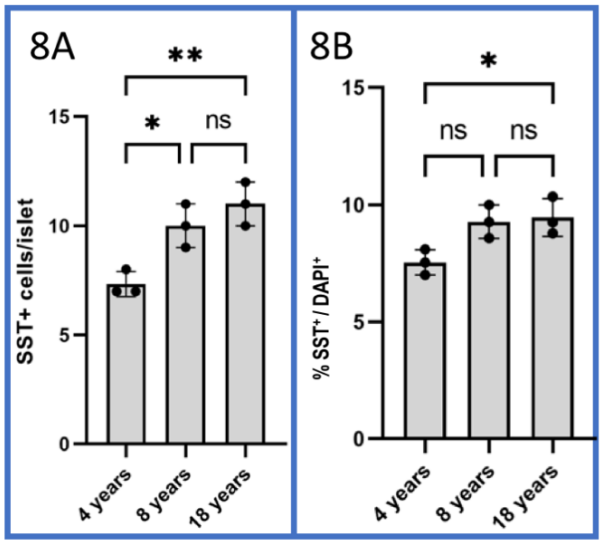

Fig. 8. Statistical analysis of the difference in the average cell number of pancreatic somatostatin (**8A)** and somatostatin hormone percentage **(8B)** in camel pancreas at three different age. Small increasing in somatostatin cells number and percentage in camel pancreas with age and almost no percentage difference between 8 years and 18 years. * $P < 0.05$, ** $P < 0.01$, ns: not significant.

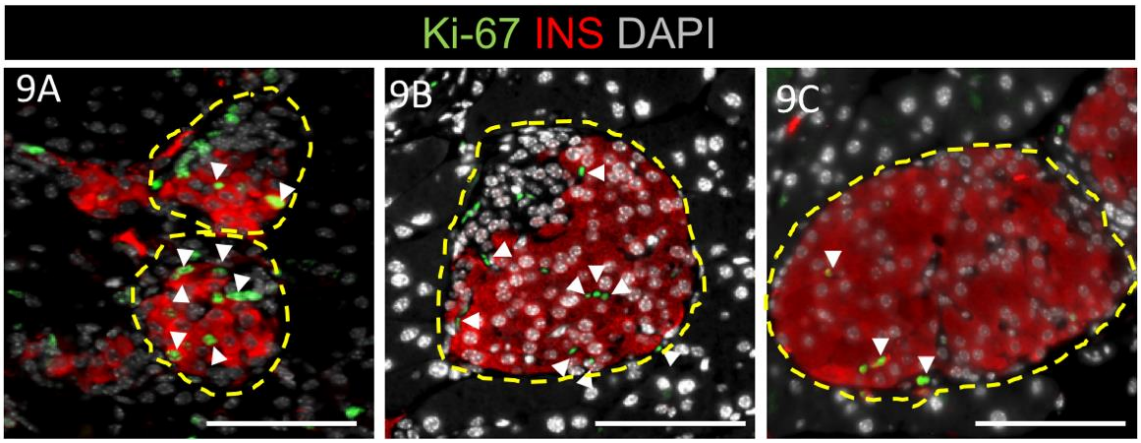

Fig. 9. Immunofluorescence staining showing proliferation in camel pancreas by using expression of Ki-67 (green) and Insulin (red), and the DAPI (white) at 4 years **(9A)**, 8 years **(9B)** and 18 years **(9C)**. The proliferation rate of beta cells increases from 4 years to 8 years then dropped down at 18 years in pancreatic islets of camel pancreas. White arrowheads show Ki-67-positive insulin+ cells. Scale bar = 50 μm.

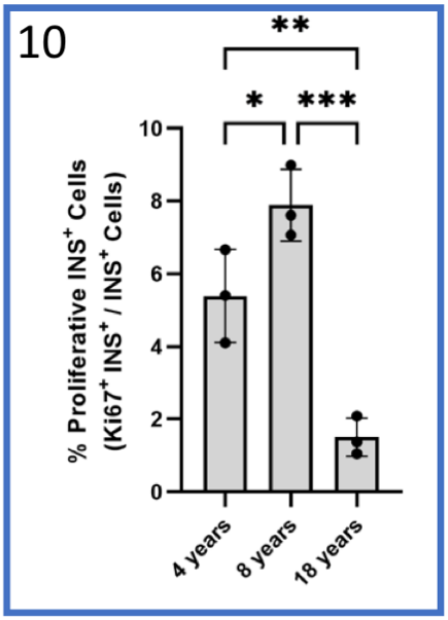

Fig. 10. Statistical analysis of the difference in the percentage of proliferation in camel pancreatic islets with age revealed increase of beta-cell proliferation from 4 years to 8 years and low percentage of proliferation in insulin cells at 18 years. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Discussion

The pancreatic islets in the present study were scattered throughout the camel pancreas and had varied shapes, which is consistent with previous research (Bargooth et al., 2020). In contrast to the findings of the current study in camels, Hafez et al. (2015) noticed clear and strong delineation in horses. Weak delineation separating pancreatic islets from exocrine acini in camel was found, which in agreement with the findings of Hafez et al. (2015) in camels. Variations in pancreatic islet shape may be related to weak and insufficient delineation, which may lead some endocrine cells to be transferred from the pancreatic islets to the exocrine acini.

Previous studies have found that the size of pancreatic islets varies between different animal species. According to Hafez et al. (2015), the pancreatic islet size in cattle was smaller than that in horses or camels based on visual assessments. Mahesh et al. (2017) found that the size of pancreatic islets in sheep is larger than that in goats. According to Bargooth et al. (2020), the pancreatic islet diameter of a buffalo is smaller than that of a camel. However, there are many studies in the pancreas of different mammals; most of the previous studies were conducted on adults only.

The present study revealed variation in the size of pancreatic islets during postnatal development of the pancreas in camels where the pancreatic islets increased in diameter with age, from 70.3 ± 1.5 µm in 4 years to 97 ± 1.6 µm in 18 years in the camel pancreas (Table. 3), which is in agreement with the results of Bargooth et al. (2020), who found that the diameter of a pancreatic islet in an adult camel was 98 ± 0.5 µm. The increase in pancreatic islet size with age may be related to the various needs of hormone secretion by the pancreatic islets for metabolism in the camel pancreas, which is primarily influenced by blood glucose levels.

The current findings revealed that insulin cells were distributed in the peripheral and central parts of pancreatic islets, which are in accordance with the results of Bargooth et al. (2020), who found that insulin cells were distributed in different areas of pancreatic islets in camels. However, the present findings contradict those of Hafez et al. (2015), who detected that β-cells were distributed in the periphery of pancreatic islets in horses.

The present study showed an increase in the insulin average from 65.7% in 4 years

to 77.6% in 18-year-old camels (Table. 3), which is in agreement with the results of Bargooth et al. (2020), which detected only one age and the percentage of β-cells was 77-88% in an adult camel. The average number of insulin cells per islet increased with age in the camel pancreas, with the number of insulin cells being 64 ± 1 cells per islet in 4 years, increasing to 78.6 ± 1.5 cells per islet in 8 years, and 90.3 ± 2 cells per islet in 18 years (Table. 3), which is in contrast with Adeghate (1997), who reported that the numbers of insulin cells per islet were 67.34 ± 14.20 and the insulin percentage was 44.26 ± 90.91%.

The current findings revealed that glucagon cells were distributed in the peripheral parts of pancreatic islets, which are in accordance with the results of Bargooth et al. (2020) in camels. These results are in an opposition to those of Hafez et al. (2015), who found that α-cells were distributed only in the center part of pancreatic islets in the horses.

The results in this present study showed an increase in glucagon average from 11.2% in 4 years to 14.8% in both 8 years and 18 years (Table. 3), which is consistent with the findings of Bargooth et al. (2020), who detected that the percentage of α-cells in an adult camel was 10-17%.The number of glucagon cells increased with age in the camel pancreas, with 11 ± 1 cells per islet in 4 years, 16 ± 1 cells per islet in 8 years, and 17.3 ± 0.5 cells per islet in 18 years (Table. 3), which contrasts with Adeghate (1997), who reported that the number of glucagon cells per islet was 23.5 ± 8.2 and the percentage was 11.4–44.4% in an adult camel.

The present findings showed that somatostatin cells are less abundant than insulin and glucagon cells and are distributed throughout the islets, which is consistent with Khatim et al. (1985); Sultan (1999); and Hafez et al. (2015) in camels. Al-Ani (1987) in camels, Bonner-Wier and Like (1980) in bovines, and Furuoka et al. (1989) in horses reported that somatostatin was present only in the peripheral part of pancreatic islets, which contrasts with the current findings.

The distribution of hormones in camel pancreatic islets showed a higher percentage of insulin, followed by glucagon, and somatostatin was the lowest percentage, which is consistent with the results of Bargooth et al. (2020) in camels.

Although there are several studies describing the proliferation of beta cells in several mammals, until now there have been no studies describing the proliferation of beta cells in the camel pancreas. Therefore, this study aimed to detect the percentage of beta cell proliferation at different ages by using Ki-67 as a proliferative marker. The proportion of beta-cells that are actively proliferating rose from 4 to 8 years of age before falling off at old age. The percentage of Ki-67 in insulin cells that were positive was 5.4% at 4 years, 7.8% at 8 years, and then it stopped rising with age and fell to 1.5% at 18 years. The results of current study in proliferation are in agreement with those of Teta et al. (2005), who reported that beta cell proliferation increased with age until adulthood, at which point it became rare in aged adult mice. Furthermore, these findings are in agreement with the findings of Bonner-Weir et al. (1989), who found that adult beta-cell proliferation happens in response to higher metabolic requirements, assisting the pancreas to regulate and produce an adequate amount of insulin in rats. Contrary to present findings, Finegood et al. (1995) demonstrated that the rate of beta cell proliferation in rats dropped from 20% in newborn pups to 2% in adulthood. Montanya et al. (2000) revealed that proliferation rates decreased from 0.8% in 1-year-old rats and remained steady at 0.2%

after that, which contrasts with the present findings.

According to Hussin (2003), the camel kidneys have an impact on glucose regulation by reabsorbing glucose from the glomerular filtrate and reintroducing it to the bloodstream. Ca++ and K+ ions play a key role in modulating the beta-cell secretion of the insulin hormone. The camel has the ability to withstand thirst and dehydration by regulating the concentrations of K+ and Ca++ ions, which have an impact on insulin release (Rutter and Hodson, 2013).

It could be inferred from the reabsorption of glucose that a high percentage of insulin hormone is most likely required in the camel to keep its blood glucose level stable, which is consistent with the present results in one-humped camels.

Conclusion

This study concluded that the pancreatic islets in the camel pancreas grow larger, and insulin production increases both proportionately and quantitatively with age. Insulin cell proliferation continued until adulthood, which could explain the high percentage of insulin cells.

Glucagon and somatostatin had low percentages and no aging-related increases. A high amount of insulin is likely required for the camel to maintain a stable blood glucose level.

Conflict of interest statement

The author declares that there is no conflict of interest.

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