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Histoarchitecture of endocrine pancreas of dog and pig

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Abstract
The present study comparatively evaluated the endocrine pancreas of dogs and pigs with reference to islet of Langerhans morphology and cellular composition. In both species, the islets of Langerhans were irregularly distributed among the acini and surrounded by sinusoidal capillaries and fine reticular fibres. Dogs exhibited three types of islets i.e large sized measuring 80 to 110 µm, medium sized 40 to 45 µm, and small sized 20 to 25 µm while, pigs possessed comparatively larger islets of Langerhans measuring 145 to 230 µm, 60 to 110 µm, and 20 to 30 µm, respectively. The number of endocrine cells per islet of Langerhans was lower in dogs (38–50, 16–20, and 1–7) than in pigs (105–123, 25–34, and 1–15). β-cells were predominant in both species, constituting 60.72 to 73.01% in dogs and 73.38 to 73.04% in pigs, whereas α, δ, and PP cells were fewer. Overall, the islets were larger, denser, and more numerous in pigs, indicating higher endocrine activity compared to dogs.

Keywords: Endocrine Pancreas, islets of Langerhans, α-cells, β-cells, δ-cells, PP cells

Introduction
The pancreas is a mixed gland comprising exocrine and endocrine components, the latter represented by the islets of Langerhans, which play a vital role in glucose homeostasis through the secretion of insulin, glucagon, somatostatin, and pancreatic polypeptide. The structural organization, distribution, and cellular composition of the islets vary considerably among animal species. Getty (1975) [13] described delicate reticular fibres forming incomplete septa within acini and enclosing irregular cords of alpha, beta, delta, and F cells in domestic animals. Weir and Orci (1982) [28] in rats classified islets into small, intermediate, and large types based on vascular patterns, while Mukherjee *et al.* (1988) [22] in sheep noted irregular clusters of endocrine cells with beta cells centrally and alpha cells peripherally arranged. Watanabe *et al.* (1989) [27] in dogs observed numerous beta cells and few alpha cells along with a neuro-insular complex containing delta-like cells. Furuzawa *et al*. (1992) [9] identified glucagon, insulin, somatostatin, and pancreatic polypeptide-producing cells in cat pancreas, while Frandson *et al.* (1992) [8] reported predominance of beta cells in domestic animals.
Ganguli and Prasad (1995) [12] described alpha and beta cells in goat islets without zonal variation, and Hiratsuka *et al.* (1996) [11] noted dumbbell-shaped islets in cattle with size differences between A- and B-cell regions. Delmann and Eurell (1998) [7] documented interspecies differences in alpha, beta, and delta cell proportions. Jay *et al.* (1999) [17] in pigs observed increased size and number of beta-cell clusters with age. Similar structural variations were reported in cats (Jagapathi *et al.*, 2012; Al-Saffar and Al-Zuhairy, 2017) [16, 3], goats (Sreeranjini *et al*., 2015; Balasundaram, 2018) [26, 4], sheep (Rohankar *et al.*, 2005; Mahesh *et al.*, 2017) [24, 21], and other mammals, indicating species-specific organization and functional adaptation of pancreatic islets. However, comparative histological information on the endocrine pancreas of pig and dog was scarce. Therefore, the present study was undertaken to conduct a comparative histological investigation of the endocrine pancreas between dog and pig.

Materials and Methods
The present study was conducted on pancreas of 9 dogs and 17 pigs of either sex. The tissue

samples of pigs were collected from AICRP on pigs, Tirupati and tissue samples of dog were collected under willed animal body programme from Veterinary Clinical Complex, College of Veterinary Science, Proddatur and Tirupati. The tissue samples of pancreas were taken at different regions of pancreas i.e body, right lobe and left lobe. Then the tissue samples were fixed in 10% Neutral buffered formalin and Bouin's fluid (Singh and Sulochana, 1996) [25]. The fixed tissues were subjected to routine tissue processing and paraffin blocks and sections of 4-5µm thickness and the sections were stained by the following methods for histological study.

1. Standard Haematoxylin and Eosin method for the routine histological stud (Singh and Sulochana, 1996) [25].
2. Masson's Trichrome method for demonstration of collagen fibres (Singh and Sulochana, 1996) [25].
3. Beilschowsky method for nerve fibres (Luna, 1968) [19].

Results

In the present study, the endocrine portion of the pancreas in both dogs and pigs consisted of irregularly distributed cellular aggregations known as islets of Langerhans, interspersed among the exocrine acini and surrounded by numerous sinusoidal capillaries (Figs.1, 2 and 3). The islets in both species were supported by fine reticular and collagen fibres, and a well-developed periinsular nerve plexus was observed extending into the central region of the islets (Figs. 4 and 5). However, distinct morphological and quantitative differences were noted between the two species.

In dogs, the islets were more numerous in the body and left lobes of the pancreas, while fewer, small foci were observed in the right lobe. The islets were classified into three categories i.e large sized (Fig. 2), medium sized (Figs.1 and 6), and small sized (Figs.1 and 6) with diameters ranging from 80–110 µm, 40–45 µm, and 20–25 µm, respectively. The number of endocrine cells per islet varied from 38–50 in large, 16–20 in medium, and 1–7 in small islets (Table.1). In contrast, the pig pancreas exhibited larger, denser, and more numerous islets, randomly distributed throughout the gland. The large sized (Fig. 7), medium sized (Fig.3), and small sized islets measured 145–230 µm, 60–110 µm, and 20–30 µm, respectively, and contained 105–123, 25–34, and 1–15 endocrine cells (Table. 2). A distinct periinsular nerve plexus (Fig.4 and 5) and occasional ganglionic cells were noted in pigs (Fig.7), indicating higher neuroendocrine integration than in dogs.

The α-cells were mainly located at the periphery of the islets in both species, though some were also found in the central zone in dogs (Figs. 1 and 2). These cells were smaller than β-cells but larger than δ and PP cells, with eccentrically placed nuclei measuring 4.25–5.28 µm in dogs and 4.77–5.37 µm in pigs (Fig. 3). The α-cells formed 24.12% and 13.69% of total endocrine cells in large and medium islets of dogs (Table. 1), compared to 16.15% and 12.33% in pigs (Table. 2), indicating a relatively higher glucagon-producing population in dogs.

The β-cells were the most predominant endocrine cell type in both species and were distributed throughout the islets (Figs. 1, 2, 3 and 8), forming cords or clusters. In dogs, β-cells constituted 60.72% of the total endocrine cells in large islets and 73.01% in medium islets (Table. 1), while in pigs, they accounted for 73.38% and 73.04%, respectively (Table. 2). The cytoplasm of these cells was pale, and nuclei were centrally or eccentrically placed, measuring 4.85–5.84 µm in dogs and 5.25–6.67 µm in pigs. Small islets in both species were composed predominantly of β-cells, suggesting their role in maintaining basal insulin secretion. The larger nuclear diameter and higher density of β-cells in pigs indicated more active insulin synthesis compared to dogs.

The δ-cells were distributed mainly along the periphery and interspersed between other endocrine cells (Figs. 1, 2, 3 and 8). They exhibited eosinophilic cytoplasm with an elongated ovoid nucleus smaller than that of α- and β-cells. The nuclear diameter ranged from 3.87–5.25 µm in dogs and 3.50–4.30 µm in pigs. The δ-cells constituted 10.19% and 8.62% of the total endocrine cells in large and medium islets of dogs (Table. 1), and 6.57% and 10.28% in pigs (Table. 2), respectively.

PP cells were the least numerous in both species and were observed singly or in small numbers at the periphery of the islets, close to the connective tissue capsule (Figs. 1, 2, 3 and 8). They were spindle-shaped with eosinophilic cytoplasm and small nuclei measuring 3.00–3.83 µm in dogs and 2.60–3.18 µm in pigs. The PP cells accounted for 4.95% and 4.61% in dogs (Table. 1) and 3.88% and 4.32% in pigs (Table. 2) for large and medium islets, respectively.

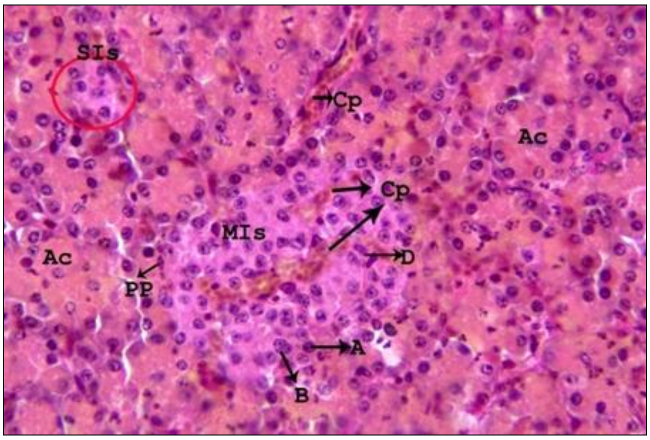

Fig 1: Photomicrograph of pancreas of dog showing different cells in islets of Langerhans with sinusoids.

- Van Gieson's x 400
- SIs – Small islet of Langerhans
- MIs – Medium sized isletof Langerhans
- A – Alpha cell
- D – Delta cell
- B – Beta cell
- Cp – Sinusoid
- PP – Pancreatic Polypeptide cell
- Ac- Acini

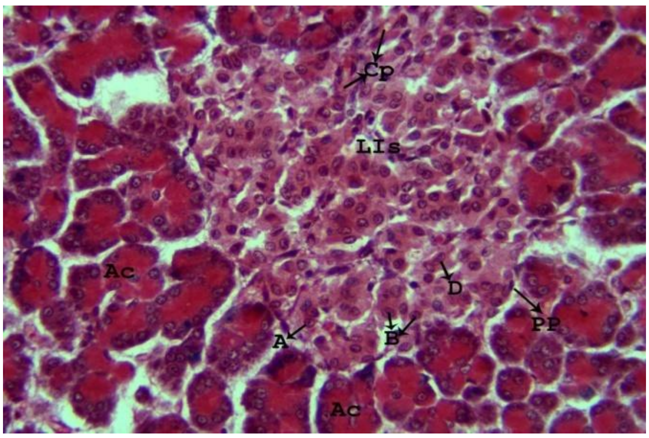

Fig 2: Photomicrograph of pancreas of dog showing different cells in islets of Langerhans.

- Masson's Trichrome x 400
- A – Alpha cell
- D – Delta cell
- B – Beta cell
- PP – Pancreatic Polypeptide cell
- Ac – Acini
- LIs – Large islet of Langerhans

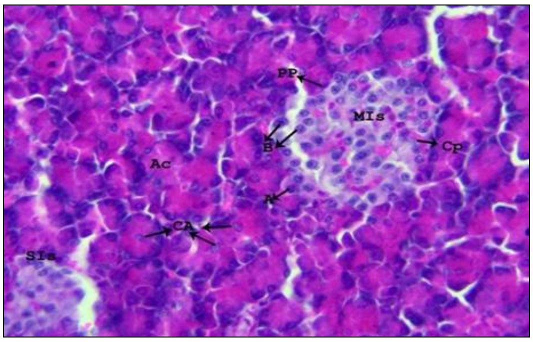

Fig 3: Photomicrograph of pancreas of pig showing different cells in medium sized islet of Langerhans.

- H & E 400
- SIs – Small islet of Langerhans
- MIs – Medium sized islet of Langerhans
- Ac – Acini
- CA – Centroacinar cell
- A – Alpha cell
- B – Beta cell
- Cp – Capillary (Sinusoid)
- PP – Pancreatic Polypeptide cell

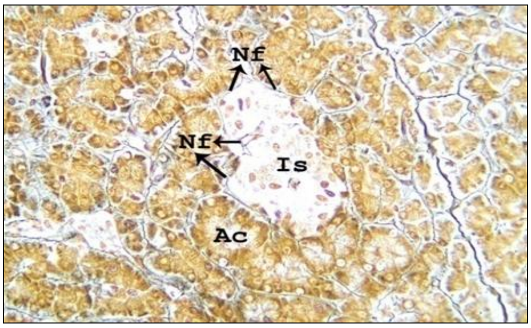

Fig 4: Photomicrograph of pancreas of dog showing periinsular nerves plexuses around the islet.

- Bielschowsky x 400
- Is – Islet of Langerhans
- Nf– Nervefibres

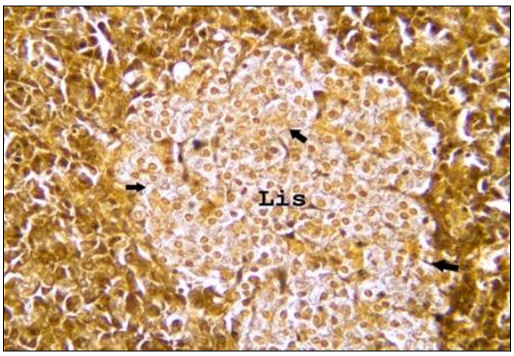

Fig 5: Photomicrograph of pancreas of pig showing periinsular nerves plexuses around the islet.

- Bielschowsky x 400
- LIs – Large islet of Langerhans
- Black arrow – Periinsular Nerve Plexus

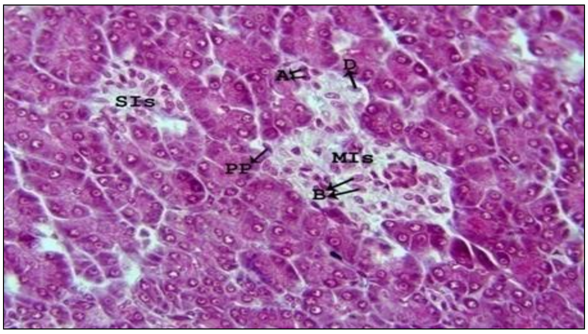

Fig 6: Photomicrograph of pancreas of dog showing different cells in islets of Langerhans.

- Masson's Trichrome x 400
- SIs – Small sized islet of Langerhans
- MIs – Medium sized islet of Langerhans
- A – Alpha cell
- D – Delta cell
- B – Beta cell
- PP – Pancreatic Polypeptide cell

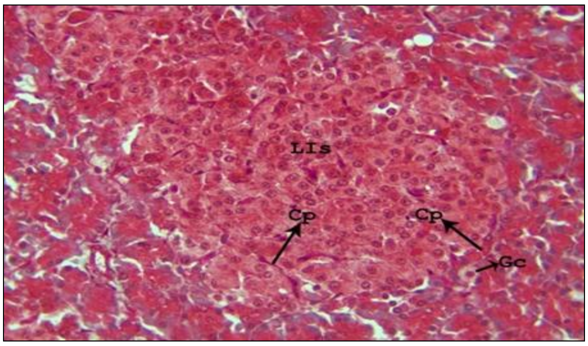

Fig 7: Photomicrograph of pancreas of pig showing sinusoids in large islet of Langerhans.

- Masson's Trichrome x 400
- LIs – Large sized islet of Langerhans
- Cp – Capillary (Sinusoid)
- Gc – Ganglionic cell

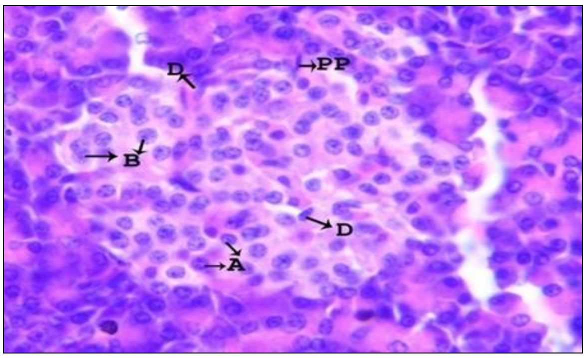

Fig 8: Photomicrograph of pancreas of pig showing different cells in medium sized islet of Langerhans.

- H & E x 400
- A – Alpha cell
- B – Beta cell
- D – Delta cell
- PP – Pancreatic Polypeptide cell

Table 1: The average number and percentage of endocrine cells in islets of Langerhans of pancreas in dog.

S. No	Type of endocrine cell	Average number of endocrine cells		Average percentage of endocrine cells	
		Large sized islet	Medium sized islet	Large sized islet	Medium sized islet
1	α cells	9 to 11	2 to 3	24.12%	13.69%
2	β cells	23 to 28	13 to 15	60.72%	73.01%
3	δ cells	4 to 7	2 to 3	10.19%	8.62 %
4	PP cells	2 to 4	0 to 1	4.95%	4.61%

Table 2: The average number and percentage of endocrine cells in islets of Langerhans of pancreas in pig.

S. No	Type of endocrine cell	Average number of endocrine cells		Average percentage of endocrine cells	
		Large sized islet	Medium sized islet	Large sized islet	Medium sized islet
1	α cells	14 to 22	3 to 7	18.83%	12.33%
2	β cells	80 to 86	18 to 21	70.97%	73.04%
3	δ cells	7 to 10	3 to 4	6.57%	10.28%
4	PP cells	4 to 5	1 to 2	3.88%	4.32%

Discussions

In the present study, the endocrine portion of the pancreas in both dogs and pigs consisted of irregularly distributed cellular aggregations known as the islets of Langerhans, which were interspersed among the exocrine acini and surrounded by numerous sinusoidal capillaries. The islets were supported by fine reticular and collagen connective tissue fibres, and a well-developed periinsular nerve plexus was observed extending into the central portion of the islets. Similar observations were reported by Frandson *et al.* (1992) [8] and Delmann and Eurell (1998) [7], who described the islets as pale-stained clumps of endocrine cells arranged in irregular cords and separated by a rich capillary network. Getty (1975) [13] also stated that delicate reticular fibres form thin incomplete septa between the acini, whereas Abunasef *et al.* (2014) [1] and Hafez *et al.* (2015) [14] recorded that fine collagen fibres surrounded the islets and their capillaries. The presence of a prominent periinsular nerve plexus in both species in the present study is consistent with Ahmed *et al.* (2017) [2], who demonstrated periinsular and perivascular nerve plexuses in the pancreas of rats, indicating significant neural modulation of endocrine secretion. Occasional ganglionic cells associated with the islets in pigs correspond with the neuro-insular complexes described by Watanabe *et al.* (1989) [27] in dogs, suggesting a higher degree of neuroendocrine coordination in the porcine pancreas.

The islets in both species exhibited distinct morphological and quantitative variations. In dogs, the islets were more numerous in the body and left lobes, while smaller foci occurred in the right lobe. The islets were classified into large (80–110 µm), medium (40–45 µm), and small (20–25 µm) categories containing approximately 38–50, 16–20, and 1–7 endocrine cells, respectively. In pigs, the islets were larger and denser, measuring 145–230 µm, 60–110 µm, and 20–30 µm, containing 105–123, 25–34, and 1–15 endocrine cells, respectively. These results are comparable with the findings of Budras *et al.* (2007) [5], who reported that islets in dogs reached up to 0.5 mm in diameter and represented 1–2% of total pancreatic tissue. Jay *et al.* (1999) [17] and Lamb *et al.* (2014) observed that porcine islets were more compact and well-developed with advancing age. Hafez *et al.* (2015) [14] also stated that the islets were more distinct and larger in pigs and horses compared to cattle and dogs. The present findings, therefore, indicate that pigs possess larger, denser, and more compact islets with higher endocrine cell density than dogs, suggesting enhanced endocrine efficiency.

The α-cells (glucagon-producing cells) were predominantly located at the periphery of the islets in both species, though a few were observed in the central zones of canine islets. These cells were smaller than β-cells but larger than δ- and PP cells, with eccentrically placed nuclei measuring 4.25–5.28 µm in dogs and 4.77–5.37 µm in pigs. Quantitatively, α-cells constituted 24.12% and 13.69% of the total endocrine cell population in large and medium islets of dogs, and 16.15% and 12.33% in pigs, respectively. These observations are in agreement with Mukherjee *et al.* (1988) [22] and Rohankar *et al.* (2005) [24], who reported similar peripheral localization of α-cells in sheep, and with Jagapathi *et al.* (2012) [16] in cats. Naggar *et al.* (1993) [23] also described α-cells forming the outer mantle of the islets in rats, surrounding centrally located β-cells. The relatively higher α-cell proportion in dogs may indicate a greater glucagon-producing activity and a higher glucose mobilization demand, reflecting species-specific metabolic adaptation.

The β-cells (insulin-producing cells) formed the major endocrine population in both species and were arranged in cords or clusters throughout the islets. They comprised 60.72% and 73.01% of total endocrine cells in large and medium islets of dogs, and 73.38% and 73.04% in pigs, respectively. Morphologically, they were polyangular with centrally or eccentrically placed nuclei measuring 4.85–5.84 µm in dogs and 5.25–6.67 µm in pigs, and exhibited pale cytoplasm with indistinct cell boundaries. These findings correspond with Delmann and Eurell (1998) [7], who reported β-cells constituting 60–80% of the total islet cells in domestic animals. Kuehnel (2003) [18] noted that β-cells formed the core of islets and were closely associated with capillaries, facilitating efficient hormone release. The larger nuclei and higher β-cell percentage in pigs suggest more active insulin synthesis compared to dogs. Bosco *et al.* (2010) [6] observed that in pigs and humans, β-cells are positioned adjacent to capillaries, enabling rapid insulin secretion. The predominance of β-cells in small islets observed in the present study agrees with Weir and Orci (1982) [28] and Jay *et al.* (1999) [17], who stated that small islets mainly function in basal insulin regulation.

The δ-cells (somatostatin-producing cells) were found interspersed among α- and β-cells and along the periphery of the islets. They exhibited eosinophilic cytoplasm and small ovoid nuclei measuring 3.87–5.25 µm in dogs and 3.50–4.30 µm in pigs, constituting 10.19% and 8.62% of total endocrine cells in large and medium islets of dogs, and 6.57% and 10.28% in pigs, respectively. These results corroborate the findings of Watanabe *et al.* (1989) [27] and Jagapathi *et al.* (2012) [16], who reported a scattered distribution of δ-cells in the pancreas of dogs and cats. Delmann and Eurell (1998) [7] described δ-cells as forming a minor component of islets, serving a modulatory role in insulin and glucagon secretion.

The pancreatic polypeptide (PP) cells were the least numerous among the endocrine cells and were found singly or in small clusters at the periphery of islets, close to the connective tissue capsule. These cells were spindle-shaped with eosinophilic cytoplasm and small nuclei measuring 3.00–3.83 μm in dogs and 2.60–3.18 μm in pigs, constituting 4.95% and 4.61% of total islet cells in dogs and 3.88% and 4.32% in pigs for large and medium islets, respectively. These observations are similar to those of Hiratsuka *et al*. (1996) [15] and Delmann and Eurell (1998) [7], who described the peripheral localization of PP cells near the exocrine tissue and their role in modulating pancreatic secretion.

From the present findings, it is evident that pigs possess larger and denser islets with a higher proportion of β-cells and a more developed periinsular nerve plexus, indicating greater endocrine and neurovascular integration, whereas dogs showed smaller and less compact islets with a relatively higher α-cell proportion. These interspecies differences reflect metabolic and physiological adaptations, as also emphasized by Hafez *et al.* (2015) [14] and Mahesh *et al.* (2017) [21], who reported that variations in islet size, structure, and cellular proportion among domestic animals correspond to their metabolic demands. Hence, although the general histoarchitecture of pancreatic islets remains conserved across species, the quantitative and morphological variations in endocrine cell types indicate functional adaptations tailored to the metabolic and endocrine requirements of each species.

Conclusion

Overall, the islets of pigs were larger, more numerous, and contained a greater number of endocrine cells than those of dogs. The predominance of β-cells in both species suggested insulin as the principal hormone of endocrine regulation; however, the higher β-cell density, larger islet diameter, and well-developed periinsular nerve plexus in pigs indicated greater endocrine activity and regulatory complexity compared to dogs. These findings highlight both structural and functional adaptations of the pancreatic islets related to species-specific metabolic demands.

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Not available

Author's Contribution

Not available

Conflict of Interest

Not available

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