Short communication

Pancreas Morphology and Duct System of Swamp Buffaloes (*Bubalus bubalis*)

Tilladit Rung-ruangkijkrai Wuthichai Klomkleaw*

Abstract

Swamp buffaloes have been important to Thai countryfolk for centuries. However, it's meat consumption has increased continuously. Since meat and offal of cattle are very similar, pancreas might be used to differentiate buffalo offal from cow offal. Pancreases from 10 adult buffaloes of both sexes were obtained and studied anatomically. Studies revealed that, unlike human and other animals, buffalo pancreas had a unique F-shape with left lobe, right lobe, body, and uncinate process. There was no main pancreatic duct. Only one accessory pancreatic duct was found open into minor duodenal papilla similar to those of cow. Furthermore, unlike human and all animals, buffalo minor duodenal papilla was situated at the caudal duodenal flexure, almost 1-foot away from the major duodenal papilla. These anatomical findings were first reported here and suggested unique characters of buffalo pancreas. These will be beneficial for initial species identification and could be fundamental information for further studies.

Keywords: buffalo, cattle, duct, human, pancreas

Department of Veterinary Anatomy, Faculty of Veterinary Science, Chulalongkorn University, Bangkok 10330, Thailand
***Correspondence:** wuthichai.k@chula.ac.th*

Introduction

Indigenous to Thailand, the swamp buffalo is classified in family *Bovidae*, subfamily *Bovinae* as bison and cattle. It is mainly found in Southern China and South-East Asian countries such as Vietnam, Laos, Cambodia, Malaysia, Philippines, Indonesia and Thailand. Thai buffaloes are often used as draft animals and also used for ploughing muddy rice fields. They are considered as loyal workers and have a deep relationship with Thailand's rural society. Data from the Ministry of Agriculture and Cooperatives (2008) showed that there were about 4.8 million buffaloes in Thailand in 1993. The buffalo population had declined dramatically to 1.6 million in 2007 due to many reasons; including an increase in buffaloes' meat consumption. In general, it is difficult to distinguish buffalo offal from cattle offal. However, pancreas is one of the unique internal organs that might be used to differentiate carcasses of these two species. Pancreas is a soft, lobulated gland with irregular shape which originated from the dorsal and ventral budlike-primordia from the glandular mucosa of small intestine in embryo (Liem et al., 2001). There are large amounts of information available on pancreas in many aspects of both humans and animals (Takahashi et al., 1977; Furuoka et al., 1989; Furuzawa et al., 1992; Hiratsuka et al., 1996; Endo et al., 1997; Kara, 2005), yet morphological investigations into the pancreas of swamp buffalo are limited. The aims of this study were to clarify the anatomical structures and the pattern of the duct system of buffalo pancreas.

Materials and Methods

Pancreases from 10 adult swamp buffaloes were obtained from a slaughterhouse in Pathumthani province, Thailand. The whole gland with duodenum were completely removed from the abdomen of each buffalo and fixed in 10% formalin. Pancreatic lobes and other related structures were identified, described, sketched and measured at macroscopic level. Measurements of the length, width and thickness of each lobe including right, left, body and uncinate processes are shown in Figure 1 and Table 1. Pancreatic exocrine ducts were observed by injection of contrast media, Omniplaque® (Amersham Health Limited, Shanghai), into accessory pancreatic duct via the minor duodenal papilla of duodenum. The Omniplaque® routes were then examined by radiography.

Results and Discussion

The pancreas of each swamp buffalo was presented in the form of an axe-like or F shape, laid in frontal plane with the apex pointing forward (Fig 1). The average total length of the pancreas was approximately 41 cm with 1.3 cm thick. It consisted of 3 main portions as follow; left lobe (L), body (B), and right lobe (R). The left lobe was wide, extended across the abdomen, insinuated between the liver, diaphragm, and great vessels dorsally and the intestine and dorsal along the descending duodenum and was connected with the body. The right lobe was about three times longer than the left lobe, measuring

Table 1 Size of pancreas of swamp buffaloes in centimeters correlated to Figure 1

		No.1 (cm)	No.2 (cm)	No.3 (cm)	No.4 (cm)	No.5 (cm)	No.6 (cm)	No.7 (cm)	No.8 (cm)	No.9 (cm)	No.10 (cm)	Average (cm)
Total length	(Tl)	46.5	44.2	43.0	42.8	38.0	34.5	37.5	40	44	38	40.85
Left lobe	**length** (Ll)	12.0	10.6	8.0	11.5	6.5	6	6	9	10.2	6.6	8.64
	width (Lw)	8.0	7.5	8.0	5.6	6.0	5.5	6	5.5	7.3	5.5	6.49
	thick (Lt)	2.1	1.6	1.8	1.5	1.7	1.4	1.6	1.5	1.7	1.5	1.64
Body	**length** (Bl)	5.2	5.9	5.5	5.8	4.0	3.5	4	5.5	6.1	4.8	5.03
	width (Bw)	4.0	5.4	4.0	5.5	4.0	3	3.5	5.5	5.5	4.5	4.49
	thick (Bt)	1.0	1.9	1.2	1.2	1.1	0.8	1.1	1.1	1.8	1.2	1.24
Right lobe	**length** (Rl)	27.0	28	30.5	26.9	20.0	20.4	21	26	28	21	24.88
	width1 (Rw1)	7.0	6.5	6.5	6.4	4.5	3.4	4.5	7.3	6.3	4.6	5.70
	width2 (Rw2)	2.3	2.2	2.5	2.2	1.5	1.7	1.5	2	2.3	1.5	1.97
	thick 1 (Rt1)	2.5	2.4	2.6	1.4	2.0	1.8	2.2	1.6	2.5	2.3	2.13
	thick 2 (Rt2)	0.6	0.6	0.4	0.7	0.6	0.5	0.6	0.6	0.6	0.5	0.57
Uncinate	**length** (Ul)	15.3	12.1	11.0	13.2	10.5	8.4	11.5	13	12.5	11	11.85
	width (Uw)	6.7	5.5	3.6	7.3	4.8	4.5	4.6	6.5	5.7	5	5.42
	thick (Ut)	1.1	1	1.6	0.9	1.2	1	1.1	1	1.1	1.1	1.11

Table 2 Size and distance between major and minor duodenal papillae

		No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10	Average
Major duodenal papilla	**length**	3.6	2	3.5	2.4	5.1	2	2.1	2.3	2.3	4	2.93
	thick	0.5	0.4	0.5	0.5	0.8	0.5	0.5	0.6	0.5	0.7	0.55
	width	1	0.8	1.1	0.7	1	0.7	0.8	0.7	0.9	0.9	0.86
Minor duodenal papilla	**length**	1.7	0.9	1.3	2	2	2	1.1	1.8	1.1	1.9	1.58
	thick	0.4	0.4	0.4	0.5	0.6	0.5	0.5	0.5	0.4	0.4	0.46
	width	0.6	0.5	0.5	0.7	0.6	0.5	0.5	0.7	0.5	0.5	0.56
Length between papillae		19.1	22.1	31.5	28.6	29	34	23	29.5	25	28.5	27.03

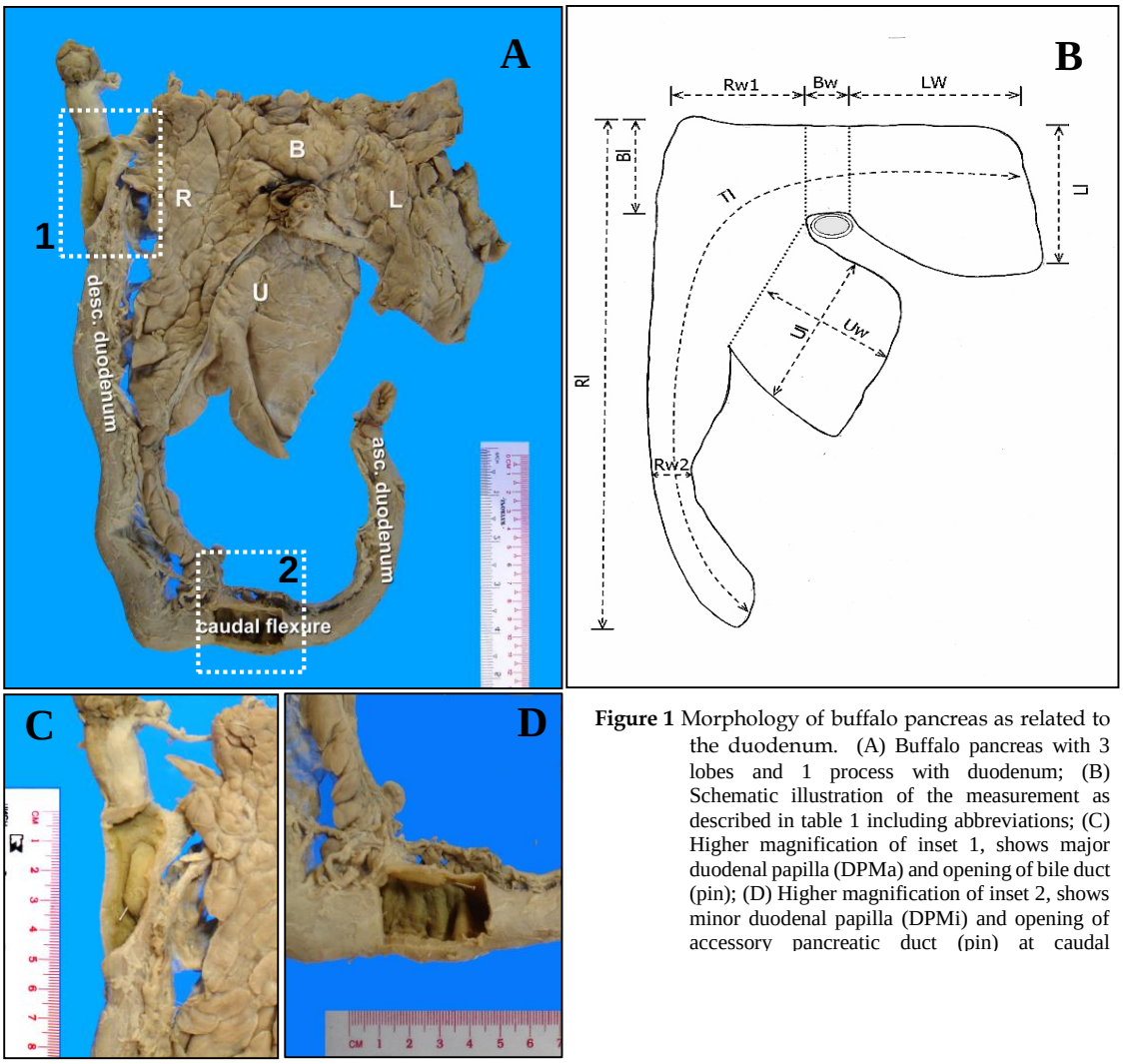

Figure 1 Morphology of buffalo pancreas as related to the duodenum. (A) Buffalo pancreas with 3 lobes and 1 process with duodenum; (B) Schematic illustration of the measurement as described in table 1 including abbreviations; (C) Higher magnification of inset 1, shows major duodenal papilla (DPMa) and opening of bile duct (pin); (D) Higher magnification of inset 2, shows minor duodenal papilla (DPMi) and opening of accessory pancreatic duct (pin) at caudal

approximately 25 cm in length (Rl) and varied in width from 1.5 to 7.3 cm (Rw) and had up to 2.1 cm in thickness (Rt). The body of pancreas was relatively small and united the two lobes. It was located cranially to and was notched by the portal vein where the gland adhered to the liver. Cranial to the pancreatic notch, the body of pancreas was about 1.2 cm thick (Bt), 4.5 wide (Bw) and 5 cm long (Bl). In addition to these three regions, a process projected laterally from the right lobe adjacent to the body was observed which could be compared to the uncinate process of human pancreas (U). The size of this part was approximately 5.4 cm, 11.9 cm, and 1.1 cm in width (Uw), length (Ul) and thickness (Ut), respectively (Table 1).

Only one accessory pancreatic duct (APD) was presented which opened into minor duodenal papilla (DPMi) at caudal duodenal flexure. No main pancreatic duct (MPD) was found in all observed buffaloes (Fig 1). Only bile duct, which received bile from the liver and gall bladder, drained into the major duodenal papilla (DPMa) at the beginning of descending duodenum. DPMi was situated at about 27 cm caudal to the DPMa. The size of DPMa was 0.9 cm in width and 3.0 cm in length while the size of DPMi was 0.6 cm in width and 1.6 cm in length (Table 2).

The duct from left lobe, right lobe and uncinate process collected the pancreatic secretion from each lobe, intercommunicated within the gland, converged at the accessory pancreatic duct as a main duct of buffalo pancreas and then entered the caudal duodenal flexure forming an F-shaped loop along the length of the pancreas as seen in the radiograph (Fig 2).

The buffalo pancreas was divided into 2 lobes, left and right, which are connected by the body, similar to other mammals (Sisson, 1975[a]; Konig and Liebich, 2007). Nomenclature of the pancreatic lobe has been reported by many researchers in the different species with the terms of splenic, gastric, and duodenal lobes which correlate to the left lobe, body, and right lobe, respectively (Takahashi et al., 1977; Furuoka et al., 1989; Endo et al., 1997).

General gross appearance of the internal organs and the shape of buffalo pancreas are supposed to be similar to that of cattle, which were both classified in the same subfamily, *Bovinae*. However, the anatomy of pancreas is obviously different between these two species. The right lobe of buffalo pancreas is distinctly elongated and has a narrow caudal extremity which cannot be found in cows and small ruminants (Habel, 1975; Dyce et al., 1996[c]) (Fig 3). In addition to the three

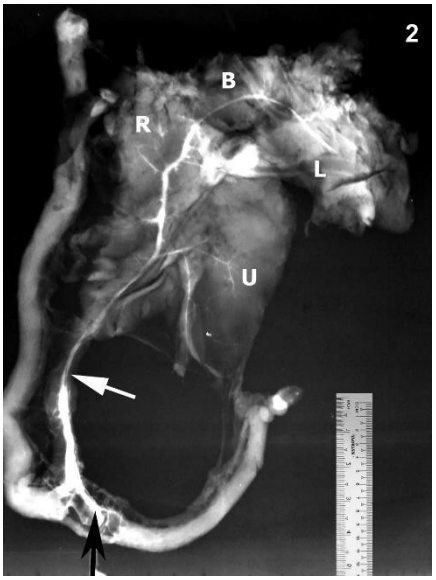

Figure 2 Radiograph of a pancreas shows accessory pancreatic duct as a main duct in buffalo (white arrow). The contrast media (Omniplauqe®) route can be seen. It was injected into the accessory pancreatic duct via minor duodenal papilla (black arrow). Alphabets mark the sampling portions. R=right lobe, B=body, L=left lobe, U=uncinate process.

regions of the pancreas, the uncinate process projects laterally from the body and right lobe but is known to be a part of the right lobe according to Nomina Anatomica Veterinaria (World Association of Veterinary Anatomists, 2012). The uncinate process that was observed in swamp buffaloes could not be found in other mammals except ruminants and humans (Langman, 1971; Hiratsuka et al., 1996; Agur and Lee, 1999). Anatomical differences between human pancreases and those of swamp buffaloes are clearly noticeable. In human, the pancreas is long, with irregularly prismatic shape, and is divided into the head, body, neck and tail (Gray, 1918), while other domestic mammal pancreas have U or V shape and are composed of the right, body, and left lobes instead (Ellenport, 1975; Ghoshal, 1975; Sisson, 1975[c]; Hiratsuka et al., 1996) (Fig 3).

In human, the uncinate process and the caudal part of the head are derived from the dorsal pancreatic primordium, while the cephalic part of the head, body, neck and tail are derived from the ventral pancreatic primordium (Larsen, 1993; Sadler, 2004). To our knowledge, there are no reports regarding the development of the buffalo pancreas available. In accordance to McGeady (2006), the left lobe of ruminant pancreas is developed from dorsal bud, while the right lobe is from the ventral bud, which arises from the liver diverticulum. As a consequence of gastric and intestinal rotation in the embryological stage of all mammalian species, the ventral and dorsal pancreatic buds overlap and fuse at the point of contact, resulting in the interconnection of ducts from each pancreatic lobes. Moreover, the ducts of pancreas undergo varying degrees of atrophy or develop at the duodenal end, resulting in adult duct configuration among species

It should be noted that the DPMa or Vater's papilla in human, an opening of MPD or duct of Wirsung which combines with the common bile duct, lies adjacent and beneath the DPMi (Gray, 1918) while the DPMi, an opening of APD in animals, is placed at the caudal to DPMa (Sisson, 1975[a]) (Fig 3).

We found that only APD or duct of Santorini in human, the persisted duct of dorsal primordia, was presented in buffalo pancreas, while the MPD was absent in all buffaloes observed, similarly in pigs (Dyce et al., 1996[d]). Without MPD, the bile duct from liver and gall bladder was found and was open on the DPMa, which is similar to those of ruminants and pigs (Habel, 1975; Dyce *et al.,* 1996[d]). On the other hand, both APD and MPD persisted in humans, dogs, hyenas, ferrets and horses, while only MPD is found in cats and small ruminants (Fig 3). These different findings in the presence of APD and MPD in various species are possibly from the development in early embryonic stage. However, to find out which stage of embryonic development these ducts regressor develop would require further investigation. (Gray, 1918; Sisson, 1975[b]; Evans and Christensen, 1979; Furuzawa et al., 1992; Dyce et al., 1996[a]; Endo et al., 1997; Agur and Lee, 1999).

In many species such as horses, dogs, pigs, small ruminant and cows, the DPMa and DPMi locate contiguously at the proximal part of descending duodenum (Habel, 1975; Ellenport, 1975; Sisson, 1975[c]; Dyce et al., 1996[c]). However, in swamp buffaloes, we investigated that the DPMi situates at the caudal duodenal flexure, which was obviously separate from the DPMa. Due to the anatomy of the buffalo pancreas, APD connects the distal end of the right pancreatic lobe, which terminates at the caudal duodenal flexure. The DPMa and DPMi of buffalo pancreas are located separately compared to other domestic animals. This might be one of the unique internal organs that could be distinguished between the cow and other ruminant species.

Kamisawa (2004) and Etue et al. (2001) reported a relationship between the size of the duct of pancreas, duodenal papilla and some diseases in humans and in cats, but still lack of information in buffaloes. The data of the size of the APD and MPD of normal buffaloes t we proposed here could be the standard value for study of the related diseases of the pancreas in buffaloes.

In conclusion, the buffalo pancreas has some distinct anatomical characteristics such as the F-shaped appearance and the opening of APD on the caudal duodenal flexure. This report could be fundamental data for future studies. It will also be beneficial to forensic identification and further investigation prior to advanced molecular techniques.

Acknowledgements

The authors would like to thank Mr. Pakorn Prachammuang for his very helpful comments and Mrs. Panida Paisiriyuenyong for the schematic illustrations.

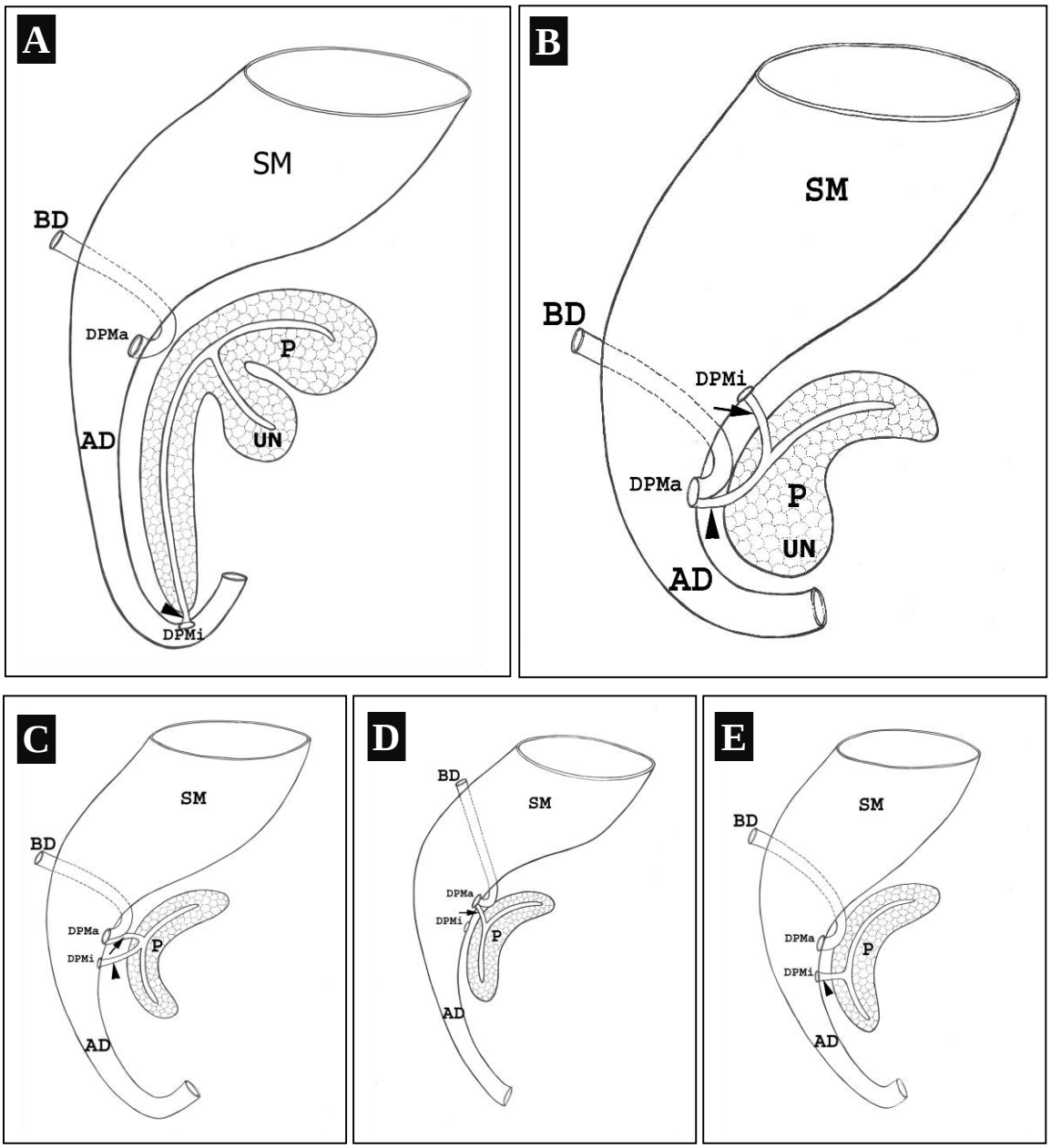

Figure 3 Schematic illustration of the stomach and pancreas of buffalo (**A**), human (**B**), horse and dog (**C**), cat and small ruminant (**D**), pig and cow (**E**).
AD=ascending duodenum, BD=bile duct, DPMa=major duodenal papilla, DPMi=minor duodenal papilla, SM=stomach, P=pancreas, UN=uncinate process, arrow=main pancreatic duct (duct of Wersung), arrowhead=accessory pancreatic duct (Santorini duct).
Notice the major duodenal papilla in the animals located cranially to the minor duodenal papilla but distally in human. Pancreatic duct is found in human, horse, dog, cat and small ruminant but not found in pig and cow, while accessory pancreatic duct is absent in cat and small ruminant.

References

Agur AMR and Lee MJ 1999. Grant's Atlas of Anatomy. 10th ed. Philadelphia: Lippincott. Williams & Wilkins. 760 pp.

Ministry of Agriculture and Cooperatives 2008. [Online]. Available: http://www.moac.go.th , Accessed Jan 15, 2013.

Dyce KM, Sack WO and Wensing CJG 1996a. The Abdomen of the Carnivores. In: Textbook of Veterinary Anatomy. 2nded. Philadelphia: W.B. Saunders company. 417-434.

Dyce KM, Sack WO and Wensing CJG 1996b. The Abdomen of the Horse. In: Textbook of Veterinary Anatomy. 2nded. Philadelphia: W.B. Saunders company. 529-550.

Dyce KM, Sack WO and Wensing CJG 1996c. The Abdomen of the Ruminant. In: Textbook of Veterinary Anatomy. 2nded. Philadelphia: W.B. Saunders company. 671-694.

Dyce KM, Sack WO and Wensing CJG 1996d. The Abdomen of the Pig. In: Textbook of Veterinary Anatomy. 2nded. Philadelphia: W.B. Saunders Company. 787-798.

Endo H, Kusanagi A, Kurohmaru M, Hayashi Y, Sakamoto K and Kimura J 1997. Pancreas morphology of the striped hyena (*Hyena hyena*). J Vet Med Sci. 59(8): 635-640.

Ellenport CR 1975. Carnivores digestive system. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders company. 1538-1558.

Etue SM, Penninck DG, Labato MA, Perason S and Tidwella A 2001. Ultrasonography of the normal feline pancreas and associated anatomic landmarks: a prospective study of 20 cats. Vet Radiol & Ultrasound. 42(4): 330-336.

Evans HE and Christensen GC 1979. The Digestive Apparatus and Abdomen. In: Miller's Anatomy of the Dog. 2nded. Philadelphia: W.B. Saunders company. 411-422.

Furusawa Y, Ohmori Y and Watanabe T 1992. Immunohistochemical morphometry of Pancreatic Islet in Cat. J Vet Med Sci. 54(6): 1165-1173.

Furuoka H, Ito H, Hamada M, Suwa T, Satoh H and Itakura C 1989. Immunocytochemical Component of Endocrine Cells in Pancreatic Islets of Horses. Nippon Juigaku Zasshi. 51(1): 35-43.

Ghoshal NG 1975. Equine Digestive System. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2. 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders Company. 454-497.

Gray H 1918. Anatomy of Human Body. 20th ed. H.L. Warren (ed.). Philadelphia: Lea & Febiger. 1396 pp.

Habel RE 1975. Ruminant digestive system. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2. 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders company. 861-915.

Hiratsuka T, Abe M, Takehana K, Iwase K, Hiraga T and Kobayashi A 1996. Immunohistochemical Analysis of the Endocrine cells in the Pancreatic Islet of Cattle. Okajimas Folia Anat. 72(6): 285-295.

Kamisawa T 2004. Clinical significance of the minor duodenal papilla and accessory pancreatic duct. J Gastroentrol. 39: 605-615.

Kara ME 2005. The Anatomical Study on the Rat Pancreas and its Ducts with Emphasis on the Surgical Approach. Ann Anat. 187(2): 105-112.

Konig HE and Liebich HG 2007. Digestive System. In: Veterinary Anatomy of Domestic Mammals Textbook and Colour Atlas. 3rd ed. Schattauer Stuttgart. 301-368.

Langman J 1971. Digestive Tube and its Derivatives. In: Medical Embryology 3rd ed. Baltimore: Williams & Wilkins Company. 258-302.

Larsen WJ 1993. Development of the Gastrointestinal Tract. In: Human Embryology. New York: Churchill Livingstone. 205-234.

Liem KF, Bemis WE, walker WFJr. and Grande L 2001. The Liver and Pancreas. In: Functional Anatomy of the Vertebrates, An Evolutionary Perspective 3rd Ed., Harcourt College Publishers. New York. 569-572.

McGeady TA, Quinn PJ, FitzPatrick ES and Ryan MT 2006. Digestive System. In Veterinary Embryology. Oxford: Blackwell Publishing Ltd. 205-224.

Muranishi T, Takehana K, Hiratsuka T, Kobayashi A, Eerdunchaolu Iwase K and Abe M 1999. An Investigation of the relationship between Duct System and A Cell-Rich and PP Cell-rich Pancreatic Islet in the Canine Pancreas. J Vet Med Sci. 61(7): 737-742.

Reighard J and Jennings HS 1935. Anatomy of the Cat 3rd and enlarged ed. New York: Hott Rinehart and Winston Inc.

Sadler TW 2004. Digestive System. In: Langman's Medical Embryology 9th ed. New York: Lippincott Williams & Wilkins. 285-320.

Sisson S 1975a. Digestive system. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2. 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders Company. 104-112.

Sisson S 1975b. Equine digestive system. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2. 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders Company. 454-495.

Sisson S 1975c. Porcine digestive system. In: Sisson and Grossman's The Anatomy of the Domestic Animals. Vol. 2. 5th ed. R. Getty (ed.). Philadelphia: W.B. Saunders Company. 1268-1282.

Takahashi M, Pour P, Althoff J and Donnelly T 1977. The pancreas of the Syrian hamster (*Mesocricetus auratus*). I Anatomical study. Lab Anim Sci. 27(3): 336-42.

World Association of Veterinary Anatomists (WAVA) 2012. Nomina Anatomica Veterinaria. 5th ed. (revised version) Knoxville. 160 pp.

บทคัดย่อ

สัณฐานวิทยาและระบบท่อในตับอ่อนของกระบือปลัก

ทิลดิสร์ รุ่งเรืองกิจไกร วุฒิชัย กลมเกลียว*

กระบือปลักมีความสำคัญต่อชาวชนบทไทยมานานนับศตวรรษ แต่การบริโภคเนื้อกระบือเพิ่มขึ้นอย่างต่อเนื่อง ความคล้ายคลึงกันระหว่างเนื้อและเครื่องในโคและกระบือทำให้ตับอ่อนน่าจะเป็นอวัยวะที่ใช้แยกแยะสัตว์สองชนิดนี้ได้ ตับอ่อนกระบือโตเต็มวัย 10 ตัว ทั้งสองเพศได้ถูกนำมาศึกษาลักษณะทางกายวิภาคอย่างละเอียดและพบว่าตับอ่อนกระบือมีรูปร่างคล้ายอักษร F ไม่เหมือนสัตว์ชนิดใดรวมทั้งมนุษย์ ประกอบด้วย left lobe, right lobe, body และ uncinate process ไม่พบ main pancreatic duct พบเพียง accessory pancreatic duct เปิดเข้าสู่ minor duodenal papilla เช่นเดียวกับในโค นอกจากนี้ minor duodenal papilla ยังอยู่ห่างจาก major duodenal papilla เกือบ 1 ฟุต ต่างจากสัตว์ทุกชนิดและมนุษย์ รายงานนี้อธิบายลักษณะทางกายวิภาคของตับอ่อนและท่อของกระบือเป็นครั้งแรก ซึ่งจะเป็นประโยชน์ในการแยกกระบือออกจากสัตว์ชนิดอื่นได้ทันทีและเป็นข้อมูลพื้นฐานเพื่อการศึกษาต่อไปในอนาคต

คำสำคัญ: กระบือ โค ตับอ่อน ท่อ มนุษย์

ภาควิชากายวิภาคศาสตร์ คณะสัตวแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กรุงเทพฯ 10330

** **ผู้รับผิดชอบบทความ E-mail:** wuthichai.k@chula.ac.th*