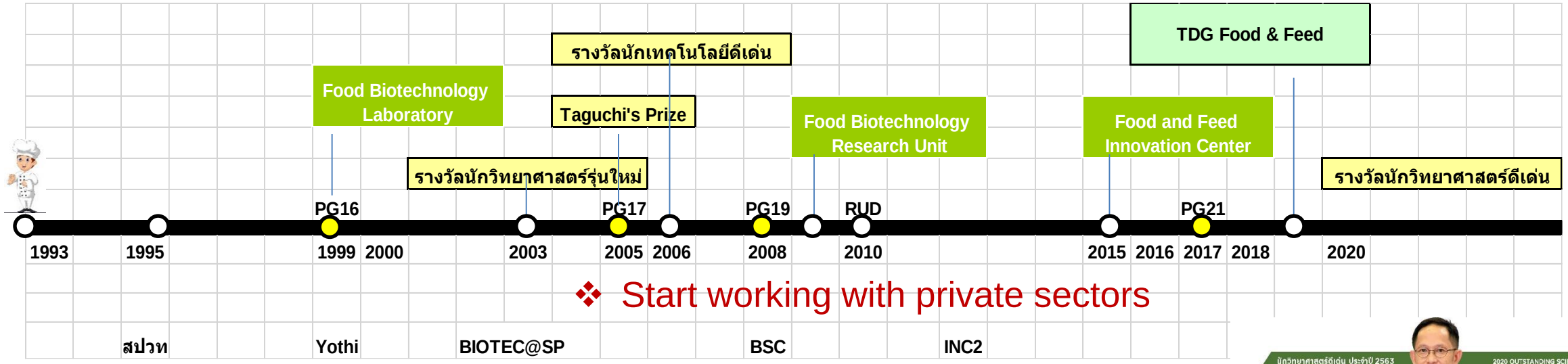
การทำงานวิจัยร่วมกับภาคเอกชนอย่างมืออาชีพ

วรรณพ วิเศษสงวน

ศูนย์พันธุวิศวกรรมและเทคโนโลยีชีวภาพแห่งชาติ
สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ

17 ธันวาคม 2563

27 Years 3 Months @ BIOTEC



Facts & Figures

Publications: 253
Petty patent: 12
Projects with private sectors: >30
Licensing: 9

H index: 51
Patents: 14
Trade secret: 10
Economic impacts: 1800 mTHB

มูลนิธิส่งเสริมวิทยาศาสตร์และเทคโนโลยีในพระบรมราชูปถัมภ์
Foundation for the Promotion of Science and Technology under the Patronage of His Majesty the King

นักวิทยาศาสตร์ดีเด่น ประจำปี 2563

ดร. วรรณพ วิเศษสงวน
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องค์ความรู้ด้านเคมีอาหารกับการยกระดับอาหารหมักไทย

เน้นศึกษาเกี่ยวกับการเปลี่ยนแปลงองค์ประกอบทางเคมีและสมบัติเชิงหน้าที่ขององค์ประกอบหลักที่เป็นส่วนผสมในการหมัก เพื่อปรับปรุงคุณภาพและกระบวนการผลิตอาหารหมักไทย นำไปประยุกต์ใช้ในด้านต่าง ๆ ดังนี้

ตัวบ่งชี้คุณภาพและแนวทางลดการสูญเสียผลิตภัณฑ์

โดยศึกษาความสัมพันธ์ระหว่างปัจจัยในการผลิตกับคุณสมบัติทางเคมี-กายภาพ และคุณสมบัติทางประสาทสัมผัสของผลิตภัณฑ์ เพื่อใช้เป็นตัวบ่งชี้ถึงคุณภาพและการยอมรับของผู้บริโภค

เครื่องมือและเทคโนโลยีเพื่อติดตามจุลินทรีย์ต้นเชื้อในกระบวนการหมัก

โดยการสร้างและใช้จุลินทรีย์ต้นเชื้อที่มีโปรตีนเรืองแสงสีเขียวร่วมกับเทคนิคทางชีววิทยาโมเลกุลใหม่ๆ ในการติดตามการเปลี่ยนแปลงกลุ่มประชากรเชื้อจุลินทรีย์ในระบบการหมัก

แบบจำลองทางคณิตศาสตร์สำหรับการคาดคะเนอัตราการหมักแหนมที่ใช้ต้นเชื้อบริสุทธิ์

โดยนำค่ากรอบต่างๆ (parameter) ในกระบวนการหมักแหนมมาสร้างเป็นแบบจำลองทางคณิตศาสตร์สำหรับการคาดคะเนอัตราการหมักแหนมที่ใช้ต้นเชื้อบริสุทธิ์ จากการเปรียบเทียบผลการคาดคะเนของแบบจำลองกับผลจากการหมักจริง พบว่ามีความถูกต้องประมาณร้อยละ 75-85

SCIENCE 2020 OUTSTANDING SCIENTIST AWARDS

มูลนิธิส่งเสริมวิทยาศาสตร์และเทคโนโลยีในพระบรมราชูปถัมภ์
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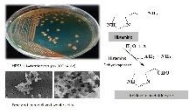
สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ (สวทช.)

การผลิตและใช้ประโยชน์เซลล์จุลินทรีย์และเอนไซม์

กระบวนการเร่งหมักน้ำปลาโดยใช้เอนไซม์ พัฒนาวิธีการหมักที่สามารถทำให้ละยะเวลาการหมัก จากปกติ18 เดือน ให้เหลือ 11 เดือน หัวน้ำปลาที่ได้มีปริมาณไนโตรเจนร้อยละ 27 มีปริมาณกรดอะมิโนอิสระที่ให้รสชาติมากกว่าน้ำปลาที่หมักด้วยวิธีปกติ



การผลิตและใช้ประโยชน์เซลล์จุลินทรีย์อาเคียในการกำจัดฮิสตามีนในผลิตภัณฑ์อาหารที่มีเกลือสูง ศึกษาองค์ความรู้พื้นฐานสำหรับการลดฮิสตามีนในน้ำปลาด้วยจุลินทรีย์อาเคียที่ชอบเกลือ รวมทั้งการออกแบบถังปฏิกรณ์ชีวภาพระบบ fixed-bed เพื่อการประยุกต์ใช้งานจริงกับน้ำปลา

ต้นเชื้อแบคทีเรียกรดแลคติกสำหรับหมักผักกาดดองเปรี้ยว ช่วยให้ผักกาดดองมีคุณภาพที่ดีขึ้น มีความสม่ำเสมอในทุกรอบการผลิต ลดการสูญเสียผลผลิต ลดต้นทุนและลดระยะเวลาในการหมักจาก 12 วัน เหลือเพียง 8 วัน

เชื้อจุลินทรีย์บาซิลลัสเพื่อเป็นอาหารหมักชีวภาพสำหรับสัตว์ สร้างเอนไซม์ที่มีความสำคัญต่อการย่อยวัตถุดิบอาหารสัตว์ สร้างสารต้านการเจริญเติบโตของจุลินทรีย์ก่อโรค สามารถกระตุ้น/ส่งเสริมสมรรถนะการเจริญเติบโตของสัตว์ได้ดีกว่าหรือเท่ากับจุลินทรีย์ที่ต้องนำเข้าจากต่างประเทศซึ่งมีราคาแพง

การพัฒนาเทคโนโลยีการผลิตเอนไซม์เสริมสำหรับสัตว์ พัฒนากระบวนการผลิตเอนไซม์รวมสำหรับสัตว์ โดยใช้เชื้อจุลินทรีย์ที่แยกได้เอง ซึ่งบริษัทเอกชนได้รับถ่ายทอดเทคโนโลยีเพื่อดำเนินการผลิตและจำหน่ายเป็นสารเสริมอาหารชีวภาพและวัตถุดิบอาหารสัตว์ที่ผ่านกระบวนการหมักทางชีวภาพ

น้ำส้มสายชูหมักจากผลไม้ในขั้นตอนเดียวและสูตรจุลินทรีย์สำหรับการหมัก สามารถลดระยะเวลาการผลิตน้ำส้มหมักของบริษัทจากเดิม 1 ปี ให้เหลือเพียง 2 - 4 เดือน กระบวนการหมักมีต้นทุนต่ำ หมักได้โดยไม่ต้องทำให้ปลอดเชื้อ ได้กรดน้ำส้มปริมาณสูง น้ำส้มหมักที่ได้มีคุณภาพและมีความปลอดภัยตรงตามเกณฑ์มาตรฐาน

SCIENCE 2020 OUTSTANDING SCIENTIST AWARDS

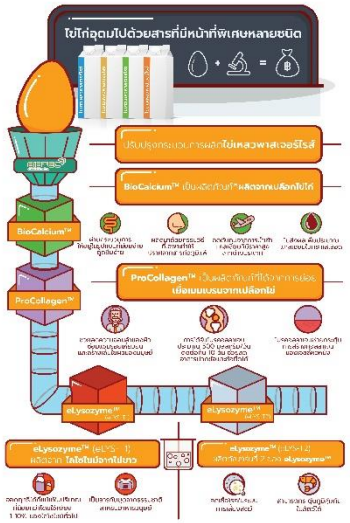
มูลนิธิส่งเสริมวิทยาศาสตร์และเทคโนโลยีในพระบรมราชูปถัมภ์
Foundation for the Promotion of Science and Technology under the Patronage of His Majesty the King

นักวิทยาศาสตร์ดีเด่น ประจำปี 2563

ดร. วรรณพ วิเศษสงวน
ศูนย์พันธุวิศวกรรมและเทคโนโลยีชีวภาพแห่งชาติ
สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ (สวทช.)

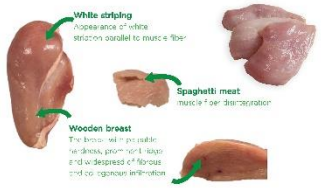
การใช้ประโยชน์จากไข่ เนื้อสัตว์และวัสดุเศษเหลือจากกระบวนการผลิตอาหาร

การใช้ประโยชน์จากไข่ครบวงจร เริ่มตั้งแต่สร้างองค์ความรู้ในการปรับปรุงกระบวนการผลิตไข่เหลวพาสเจอร์ไรส์ (ไข่ขาว ไข่แดง และไข่รวม) พัฒนากระบวนการผลิตผงแคลเซียมเปลือกไข่ และพัฒนาผลิตภัณฑ์ที่ได้จากการย่อยเยื่อเมมเบรนจากเปลือกไข่ รวมทั้งพัฒนาผลิตภัณฑ์ที่มีฤทธิ์ยับยั้งแบคทีเรียก่อโรคและแบคทีเรียที่ทำให้อาหารเน่าเสียจากไข่ขาว



การสร้างองค์ความรู้และการวิจัยด้านวิทยาศาสตร์เนื้อสัตว์ เพื่อการปรับปรุงคุณสมบัติหน้าที่ของโปรตีนกล้ามเนื้อ ที่เป็นปัญหาในอุตสาหกรรมเนื้อสัตว์ ทำให้เกิดความเข้าใจในเรื่องต่าง ๆ ซึ่งจะเป็นพื้นฐานสำคัญสำหรับการพัฒนาวิธีการจัดการที่เหมาะสม ช่วยลดหรือลดความรุนแรงของปัญหาที่เกิดขึ้นทำให้อุตสาหกรรมเนื้อสัตว์มีความมั่นคงและยั่งยืน

Meat defects in modern broilers



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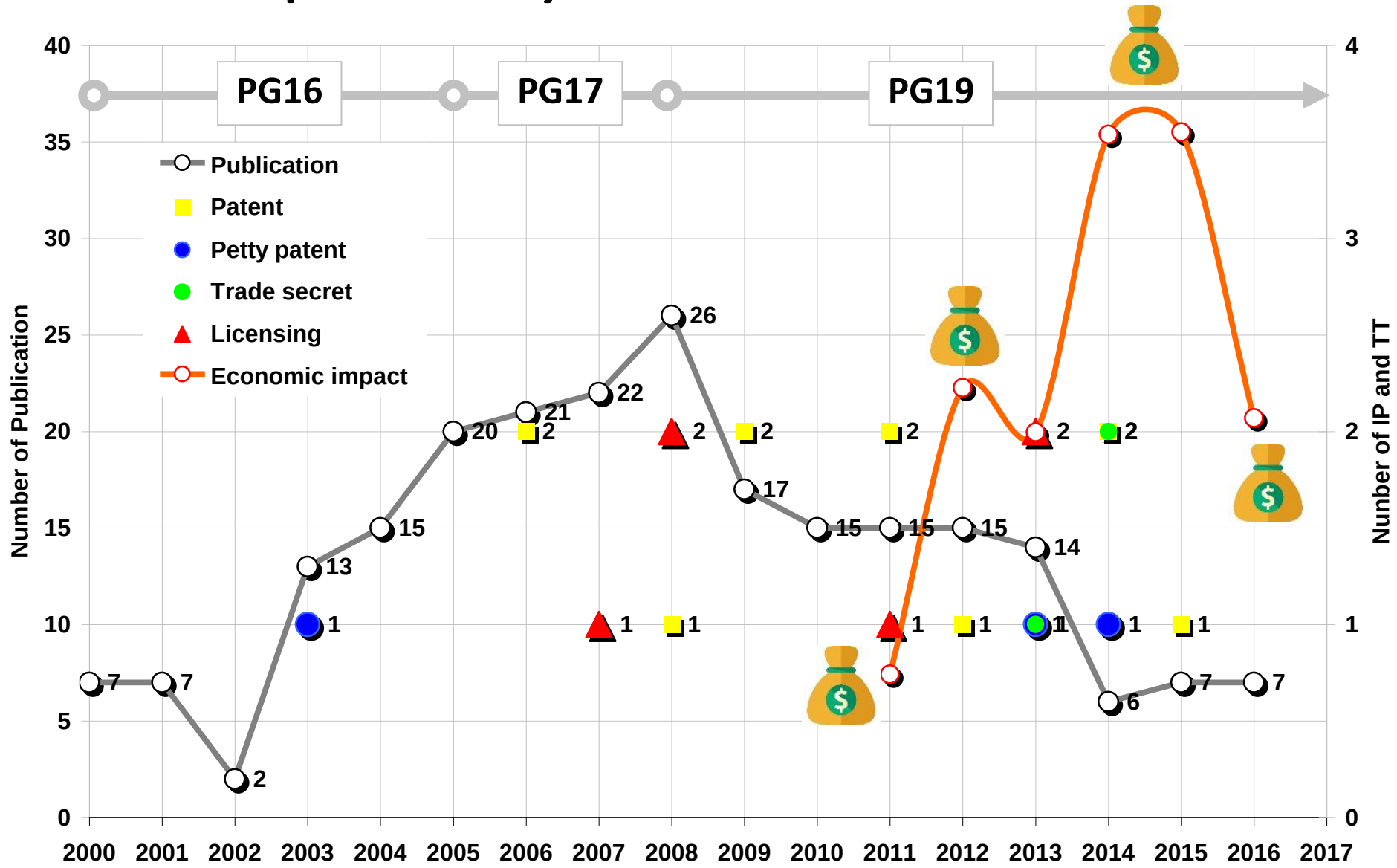
> ผู้สร้างสรรค์ต่อยอดภูมิปัญญาอาหารหมักไทย ด้วยวิทยาศาสตร์ทางอาหารและเทคโนโลยีชีวภาพ ร่วมกับพันธมิตรสร้างทางเลือกในการแก้ไขปัญหาในการผลิตและแปรรูป ยกระดับคุณภาพและมาตรฐาน สร้างอุตสาหกรรมอาหารใหม่มูลค่าเพิ่มด้วยนวัตกรรม

มูลค่าผลกระทบทางเศรษฐกิจสะสม

1,800 ล้านบาท

จากความเชี่ยวชาญด้านเคมีอาหารสู่งานวิจัยพื้นฐานและงานวิจัยประยุกต์ สร้างสรรค์นวัตกรรมเพื่อยกระดับอุตสาหกรรมอาหารของประเทศ โดยการทำงานร่วมกับพันธมิตรทั้ง มหาวิทยาลัย ภาคเอกชน และหน่วยงานต่างประเทศ

Research productivity 2000-2017



= 100 million THB

ชื่อผลงาน/เทคโนโลยีที่สร้างผลกระทบ		2562 ล้านบาท	รวม จนถึง 2563 ล้านบาท
อาหาร	การพัฒนากระบวนการเร่งหมักน้ำปลาโดยใช้เอนไซม์		67
	สูตรเชื้อจุลินทรีย์ในการผลิตต้นเชื้อแหนมและการใช้ต้นเชื้อจุลินทรีย์ในการหมักแหนม		Ongoing
	การหมักผักกาดเขียวปลีด้วยต้นเชื้อ *L. plantarum*		0.72
	การศึกษาสมบัติทางกายภาพและสมบัติทางเคมีของไข่	23.60	Ongoing
	การผลิตน้ำส้มสายชูหมักจากมังคุด		Ongoing
	การพัฒนากระบวนผลิตชีวมวลของเชื้อจุลินทรีย์โพรไบโอติก *Lactobacillus paracasei* SD1 ให้ได้ปริมาณสูง	0.09	Ongoing
อาหารสัตว์	เทคโนโลยีกระบวนการผลิตเอนไซม์เพนโตซาเนสจากเชื้อราสายพันธุ์ *Aspergillus* sp.BCC7178 เพื่อใช้ในอุตสาหกรรมอาหารสัตว์	25.43	370
	การอนุญาตให้สิทธิการใช้เชื้อแบคทีเรีย และการถ่ายทอดเทคโนโลยีการผลิตต้นเชื้ออาหารหมักสัตว์	138.76	1,250
	สารทดแทนไขมันต่อการย่อยของอาหารสัตว์และการดูดซึมกลูโคส	4.23	Ongoing
	รวม	168.51	

Economic Impact

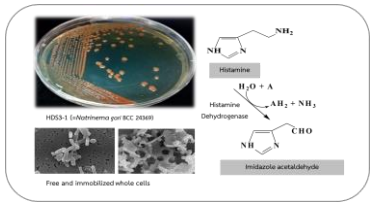
Social Impact

Environmental Impact

Production and utilization of microbial cells and enzymes

Accelerated fermentation process of fish sauce
Develop an enzyme process to shorten the fermentation period from 18 to 11 months while maintaining the unique flavor of the brand.

Production and utilization of halophilic archaea to degrade histamine in high-salt fermented fishery products



Lactic acid bacteria for fermentation of sour pickled mustard green
Select a suitable strain of lactic acid bacteria for fermentation of pickled mustard green that resulted in physical, chemical, sensory properties preferred by consumers and met a safety standard.

Fermented soy products for animal feed
Selected *Bacillus* strains that were able to both produce key enzymes that are important for digestion of feed ingredients and generate antimicrobial compounds against pathogenic microbes.

Development of technology for production of enzyme for feed additive Scale-up production of multi-enzyme preparation from *Aspergillus niger* BCC7178" for animal feed enzyme supplement.

Benefits and impacts on food producers and consumers

A-Zyme Feed Additive (*Aspergillus* sp.)

Multi-enzyme preparation *Aspergillus* sp.

370 mTHB (2007-2020)

DS-1 Feed Additive (*Bacillus* sp.)

Starter culture and fermentation process for *Bacillus* sp. as feed additive. Benefit to farm operators (better yield and healthier animals.

1250 mTHB (2010-2020)

Premium Fish sauce for export

Acceleration of the fish sauce with enzyme

270 mTHB (2012-2014)

1,800 Million THB+

Other products in commercial pipeline

Mangosteen cider vinegar (Heathy drink product)

Pineapple cider vinegar

eLysozyme™ (eLYS-T1, eLYS-T2)

Recipe of success

- Technological capability and readiness
- Mindset & Responsibility
- Strategic thinking
- Trust
- Networking
- Timing
  (*Speed ** quality and ***Ability to Deliver)
- Effective communication
- Teamwork

Excellence & Relevance >>>> Impact & Visibility

2004

ELSEVIER

Meat Science 66 (2004) 579–588

MEAT SCIENCE

www.elsevier.com/locate/meatsci

Changes in composition and functional properties of proteins and their contributions to Nham characteristics

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[b] Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand

Received 16 May 2003; received in revised form 26 June 2003; accepted 26 June 2003

Abstract

Changes in composition and functional properties of proteins during fermentation of Nham, a Thai-fermented sausage, were studied. An alkaline-soluble fraction constituted a major protein component of Nham. The amount of each protein fraction in Nham varied, depending on the fermentation time. As fermentation proceeded, the progressive decrease in sarcoplasmic and myofibrillar protein fractions was accompanied by an increase in the alkaline-soluble fraction and non-protein constituents ($P < 0.05$). Slow pH lowering to pH 4.6 during fermentation as a result of bacterial growth and accumulation of lactic acid affected the molecular conformation of the muscle proteins and resulted in changes in protein functional properties. The acid produced resulted in changes in solubility, water-binding capacity, textural properties, and color characteristics. Proteolysis of Nham proteins occurred during fermentation, resulting in increases in TCA-soluble peptides and free α-amino acids, which may contribute to the taste and aroma of Nham.

Keywords: Fermented pork sausage; Acid-induced gelation; Functional property

1. Introduction

Fermentation is one of the oldest techniques in food preservation as it not only extends the shelf-life but also enhances the flavor and nutritional quality of the product. Nham is a Thai-style fermented pork sausage, which has gained popularity with an estimated production value of 20 million USD annually. Nham is normally made of minced pork, shredded cooked pork rind, 2–3% NaCl, cooked rice, garlic and 100–125 ppm of sodium nitrite, mixed well and wrapped tightly in banana leaves or plastic bags. Fermentation of Nham generally takes 3–5 days at room termperature (~30 °C) without further ripening. Nham usually has a pH of 4.4–4.8 with titratable acidity values of 0.77–1.60% (Phithakpol, Varanyanond, Reunmaneepaitoon, & Wood, 1995).

Fermentation of Nham remains indigenous relying on adventitious microorganisms to initiate the fermentation. The initial flora of Nham derives mainly from the raw materials (Khieokhachee et al., 1997). Valyasevi, Jungsiriwat, Smitinont, Praphailong, and Chowalitnitithum (2001) suggested that fermentation of Nham involved successive growth of different microorganisms dominated by lactic acid bacteria (LAB). During the fermentation of Nham, lactobacilli (*L. plantarum*, *L. pentosus* and *L. sake)* and pediococci (*P. acidilactici* and *P. pentosaceus)* have been shown to be the dominant microorganisms (Tanasupawat & Daengsubha, 1983; Tanasupawat et al., 1992; Valyasevi et al., 2001). LAB produce organic acids from carbohydrates and cause the pH drop, which contribute to Nham formation and the inhibition of undesirable microorganisms. *Micrococcus* and *Staphylococcus* are capable of reducing nitrate to nitrite, which is important in producing the characteristic pigmentation. Also, as a source of lipolytic and proteolytic enzymes, they may contribute to flavor production.

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Influence of crude xylanase from *Aspergillus niger* FAS128 on the *in vitro* digestibility and production performance of piglets

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Abstract

The influence of crude xylanase produced from *Aspergillus niger* FAS128 or FAS128 on the *in vitro* digestibility of pig diets and production performance of piglets was investigated in comparison with two commercial crude enzyme products, IE1 and IE2. The addition of FAS128 in all pig diets resulted in higher *in vitro* digestibility of dry matter (DM), crude fibre (CF), ether extract (EE), and ash than those supplemented with IE1 and IE2 ($P<0.05$). In 6-week feeding trials, weaned piglets fed with diets supplemented with FAS128 had a significantly higher average daily gain (ADG) and lower feed conversion ratio (FCR) than those given diets with IE1 and IE2 ($P<0.05$). The incidence of diarrhoea and concentration of blood urea nitrogen (BUN) of piglets at all growth period was also lowered. Based on the improved *in vitro* digestibility and production performance, crude xylanase produced from *A. niger* FAS128 has the potential for use as feed enzyme supplement.

Keywords: Xylanase; *Aspergillus niger*; Digestibility; Production performance; Pig

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EMT

Degradation of histamine by extremely halophilic archaea isolated from high salt-fermented fishery products

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ABSTRACT

The presence of high level of histamine is detrimental to the quality and safety of fish sauce. Therefore, this study aimed to study the ability of extremely halophilic archaea to reduce histamine under high salt condition and to examine the enzyme activity potentially involved. Of 156 extremely halophilic archaea isolated from various salt-fermented fishery products, HDS3-1 from an anchovy fish sauce sample fermented for 3 months, exhibited the highest histamine degradation activity when cultured in halophilic medium containing 5 mM histamine (free-base), followed by HDS1-1, HPC1-2, and HIS40-3, respectively. HDS3-1 was classified as *Natrinema gari* based on 16S rRNA gene sequence similarities and did not exhibit decarboxylase activity toward all tested amino acids. Based on *in vitro* cytotoxicity assay, the treatment with whole cell extract of HDS3-1 to all cell lines tested resulted in dose-dependent inhibitions of the cell growth with the IC_{50} values higher than 250 μg ml^{-1}. Histamine-degrading activity of HDS3-1 was located in the intracellular fraction and required 1-methoxy-5-methylphenazinium methylsulfate (PMS) as an electron carrier. The optimal pH, salt concentration, and temperature for histamine degradation were pH 6.5–8, 3.5–5 M NaCl, and 40–55 °C, respectively. The activity was fully retained at pH 6.5–9, in the presence of NaCl above 2.5 M, and at temperature lower than 50 °C. The results suggested that histamine-degrading activity of HDS3-1 was most likely associated with salt-tolerant and thermo-neutrophilic histamine dehydrogenase.

1. Introduction

The presence of high levels of histamine is detrimental to the quality and safety of foods, particularly fish sauce and other fermented fishery products from scombroid species. Histamine in foods is mainly induced by histamine decarboxylase activity from several kinds of bacteria. The presence of histamine in fermented foods does not usually represent any health hazard to individuals unless large amounts are ingested. Typical symptoms may be observed in certain individuals, and include nausea, sweating, headache, and hyper- or hypotension [1]. The Food and Drug Administration (FDA) established an advisory level of 500 ppm to be toxic to human health [2]. Histamine is heat stable and is not detectable through organoleptic analysis by even trained panelists. Except for the gamma irradiation, no other food processing methods are available for histamine degradation [3]. Therefore histamine, if present, is difficult to destroy and posts a risk of food intoxication.

The presence of histamine-degrading enzymes either histamine oxidases or histamine dehydrogenases has been reported in various higher organisms [4–6] as well as in microorganisms [7–10]. Therefore, the application of starter strains possessing histamine-degrading activity might be a way for decreasing the amount of histamine produced *in situ* [5,7]. Nevertheless, the applications of these microorganisms and enzymes have been restricted by unfavorable physiological conditions for growth and enzyme activity such as low oxygen concentration, low pH value, undesirable temperature, and especially in the high salinity. The extremely halophilic archaea, in particular, are well adapted to saturated NaCl concentrations (grow optimally above 3.4–5.1 mol l^{-1} or 20–30% NaCl). They have a number of novel molecular characteristics, especially for their enzymes that function in high salt concentration (3–4 M NaCl), such as lipase [11], protease [12], and glucose dehydrogenase [13]. Therefore, in this present study, extremely

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Two putatively novel bacteriocins active against Gram-negative food borne pathogens produced by *Weissella hellenica* BCC 7293

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ABSTRACT

Weissella hellenica BCC 7239, isolated from Thai fermented pork sausage called Nham, produced two putatively novel bacteriocins, 7293A and 7293B. Both bacteriocins had broad antimicrobial spectra and exceptionally inhibited several important Gram-negative food-borne pathogens (*Pseudomonas aeruginosa*, *Aeromonas hydrophila*, *Salmonella* Typhimurium and *Escherichia coli*). The highest amount of bacteriocin was produced in MRS and APT media at 30 °C without agitation. Bacteriocin 7293A showed relatively higher antimicrobial activity than bacteriocin 7293B. However, pH and thermal stability of bacteriocin 7293A was lower. These bacteriocins were of proteinaceous nature, in which the complete inactivation of their antimicrobial activity after treatment by proteolytic enzymes, including trypsin, α-chymotrypsin, pepsin and protease K was observed, whilst lipase and α-amylase exhibited no effect. Antimicrobial activity of both peptides was also not inactivated by organic solvents (ethanol, isopropanol, acetone, acetonitrile) and surfactants (Tween 20, Tween 80 and Triton X-100). Bacteriocin 7293A and B exhibited bactericidal effect against both Gram-positive and Gram-negative indicators without cell-lysis. According to ESI/MS analysis, the molecular masses of bacteriocin 7293A and B were determined to be 6249.302 and 6489.716 Da, respectively. Because their molecular masses were not similar to those of other known bacteriocins, both bacteriocin 7293A and B could be novel bacteriocins. Thus, both novel bacteriocins hold promise for applications in the prevention or treatment of pathogenic infections as food and feed additives to replace antibiotics for enhancing the productivity and sustainability of food animals.

1. Introduction

One of the most important problems always found in food industry is the contamination of pathogenic bacteria (Marie et al., 2012). Among the techniques used to control the microbial contamination in food, the application of natural antimicrobial agents has received wide attention. The demand for natural, chemical preservative-free, minimally processed, and healthy products with microbial safety is increasing (Deegan, Cotter, Hill, & Ross, 2006; Papagianni & Anastasiadou, 2009). Bacteriocins or antimicrobial peptides produced by lactic acid bacteria (LAB) are members of natural antimicrobial agents which have received great attention (Cleveland, Montville, Nes, & Chikindas, 2001; Cotter, Hill, & Ross, 2005; Zacharof & Lovitt, 2012). Although many bacteriocins from LAB, such as nisin and pediocin, have been approved and widely used in food products (Zacharof & Lovitt, 2012), the inability to inhibit Gram-negative pathogens limits their applications (Cleveland et al., 2001; Deegan et al., 2006; Gillor, Etzion, & Riley, 2008). Some bacteriocins from LAB could exhibit antimicrobial activity against Gram-negative bacteria when unpurified form was used (Bendjeddou, Fons, Strocker, & Sadoun, 2012; De Kwaadsteniet, Todorov, Knoetze, & Dicks, 2005; Gong, Meng, & Wang, 2010; Jena, Trivedi, Chaudhary, Sohoo, & Seshadri, 2013; Lin, Tsai, Lin, Tsen, & Tsai, 2008; Marie et al., 2012; Ravi, Prabhu, & Subramanyam, 2011) or they were used together with chelating agent such as EDTA (Cutter & Siragusa, 1995; Lappe,

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Bacteriocins from lactic acid bacteria and their applications in meat and meat products

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ABSTRACT

Meat and meat products have always been an important part of human diet, and contain valuable nutrients for growth and health. Nevertheless, they are perishable and susceptible to microbial contamination, leading to an increased health risk for consumers as well as to the economic loss in meat industry. The utilization of bacteriocins produced by lactic acid bacteria (LAB) as a natural preservative has received a considerable attention. Inoculation of bacteriocin-producing LAB cell as starter or protective cultures is suitable for fermented meats, whilst the direct addition of bacteriocin as food additive is more preferable when live cell of LAB could not produce bacteriocin in the real meat system. The incorporation of bacteriocins in packaging is another way to improve meat safety to avoid direct addition of bacteriocin to meat. Utilization of bacteriocins can effectively contribute to food safety, especially when integrated into hurdle concepts. In this review, LAB bacteriocins and their applications in meat and meat products are revisited. The molecular structure and characteristics of bacteriocins recently discovered, as well as exemplary properties are also discussed.

1. Introduction: the need for natural antimicrobials in meat application

Microbial contamination causes serious safety and quality problems in meat industry. Meat and meat products, particularly fresh meat, contain adequate amount of water and abundance of proteins and essential nutrients with favorable pH for supporting microbial growth. The microorganisms present on meat and its products are in broad spectrum, ranging from bacteria to yeasts, molds and viruses, depending on type of the products. By far, microbial issues in meat industry have arisen mostly due to bacteria (Hui, 2012). As reviewed by Jayasena and Jo (2013), the main spoilage bacteria in meat include *Pseudomonas*, *Acinetobacter*, *Brochothrix thermosphacta*, *Moraxella*, *Enterobacter*, *Lactobacillus*, *Leuconostoc*, and *Proteus*. Upon a substantial growth of those spoilage organisms, proteins and lipids of meat and meat products undergo degradation, adversely changing appearance, texture and flavor of the products (Borch, Kant-Muermans, & Blixt, 1996). Normally, spoilage microbes do not harmfully affect health but they can stimulate gastrointestinal disturbances when consumed in high concentrations (Jayasena & Jo, 2013).

In addition to microbial spoilage, meat and its products are also prone to contamination by pathogenic microorganisms. Nine major pathogenic bacteria associated with meat and meat products include *Salmonella* spp., thermophilic *Campylobacter jejuni*, enterohemorrhagic *Escherichia coli* O157:H7, *Clostridium perfringens*, anaerobic *Clostridium botulinum*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, and *Yesinia enterocolitica*, causing illness or even death in humans (Hui, 2012). The outbreaks caused by contamination of those pathogens in meat are steadily occurred. An example of the recent foodborne outbreak results from the contamination of *Salmonella* in pork reported during April to September 2015 from five states along the West Coast of the US (Center of Disease Control and Prevention, 2015), leading to a major recall of more than 520,000 pounds of pork from the responsible company (Johnston, 2015). This multistate outbreak resulted in a total of 192 ill people, 30 were hospitalized. Luckily, no death was reported in this case. The incidence, however, instantly became headlines in global-wide media, raising consumer suspicion in safety of meat and its products.

Application of physical and chemical technologies has been employed to inactivate microbes in meat and meat products. Physical processes, such as freezing, refrigerating or thermal processing, however, may not completely assure safety of meat and its products and meet consumer satisfaction. Antimicrobial agents have been widely used. Incorporation of antimicrobial compounds with non-thermal

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Differences in textural properties of cooked caponized and broiler chicken breast meat

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ABSTRACT This study was aimed at evaluating textural properties of cooked chicken breast meats obtained from 3 production systems (conventional raising, feed modification, and caponization) and determining the relationship between instrumental parameters and sensory attributes associated with the texture of capon meat. Texture of cooked breast meats was determined using 3 instrumental methods: Warner-Bratzler Shear (WBS), texture profile analysis (TPA), and uniaxial compression (UC), and sensory analysis by trained panelists. The results indicated that cooked caponized meat showed the lowest values of WBS force, shear energy, hardness, Young's modulus of UC, and the 2 sensory attributes (firmness and number of chews) ($P < 0.05$). In contrast, springiness and juiciness were the highest in the caponized meat ($P < 0.05$), suggesting that capon meat was more tender and juicier than the others. Feed-modified chicken samples showed intermediate textural characteristics between the samples of capon and conventionally raised broiler. Pearson's correlation revealed that WBS force, shear energy, Young's modulus of UC, gumminess, and springiness were strongly correlated with 3 sensory attributes (firmness, number of chews, and juiciness). Partial least squares regression (PLSR) demonstrated that 72% of all sensory attributes for the first 2 PLSR components were explained by 36% of the instrumental parameters and the production systems. Loading and score plot illustrated that conventional raising contributed to a high degree of firmness and number of chews, and positively correlated with shear energy, WBS force, gumminess, hardness, and Young's modulus. Contrarily, caponization was negatively correlated with those sensory attributes. The univariate analysis indicated that firmness and number of chews were positively correlated with all instrumental parameters, except springiness. Juiciness was positively correlated with springiness but negatively correlated with the others. The study suggested that the cooked meat of capons could be differentiated from those of broilers raised conventionally and with feed-modified diets based on textural properties. Based on the optimized simulating equation, texture of caponized breast could be explained by WBS force, shear energy, Young's modulus, and gumminess.

Key words: capon meat, instrumental, texture, sensory attributes, partial least squares regression

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INTRODUCTION

Broilers have been a predominant poultry consumed globally as they are an inexpensive, good source of high-quality protein. Nonetheless, a number of consumers also demand different varieties of poultry and their products. In this aspect, the caponized chicken or capon, a male chicken with tastes artificially removed, has gained more popularity due to its unique textural characteristics. Capon meat is not only tender and juicy, but it also provides stickiness and gumminess characteristics to some extent. Initially, caponization applies a surgical operation or implantation of a synthetic hormone (hexoestrol) to manifest sexual maturation of male chickens, resulting in tremendous changes in physical characteristics and fat accumulation in the birds (Tor et al., 2002; Miguel et al., 2008; Sirri et al., 2009). The increased fat, including abdominal, subcutaneous, and intramuscular fat, enhances flavor, juiciness, and tenderness of the meat (Mast et al., 1981; Chan et al., 2005; Sirri et al., 2009). However, tastes removal via surgical operation has raised some ethical concern. Furthermore, hormone implantation has

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Absolute expressions of hypoxia-inducible factor-1 alpha (*HIF1A*) transcript and the associated genes in chicken skeletal muscle with white striping and wooden breast myopathies

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Abstract

Development of white striping (WS) and wooden breast (WB) in broiler breast meat have been linked to hypoxia, but their etiologies are not fully understood. This study aimed at investigating absolute expression of hypoxia-inducible factor-1 alpha subunit (*HIF1A*) and genes involved in stress responses and muscle repair using a droplet digital polymerase chain reaction. Total RNA was isolated from pectoralis major collected from male 6-week-old medium (carcass weight ≤ 2.5 kg) and heavy (carcass weight > 2.5 kg) broilers. Samples were classified as "non-defective" (n = 4), "medium-WS" (n = 6), "heavy-WS" (n = 7) and "heavy-WS+WB" (n = 3) based on abnormality scores. The *HIF1A* transcript was up-regulated in all of the abnormal groups. Transcript abundances of genes encoding 6-phosphofructo-2-kinase/fructose-2,6-biphosphatase 4 (*PFKFB4*), lactate dehydrogenase-A (*LDHA*), and phosphorylase kinase beta subunit (*PHKB*) were increased in heavy-WS but decreased in heavy-WS+WB. Glyceraldehyde-3-phosphate dehydrogenase (*GAPDH*) was up-regulated in non-defective samples. The muscle-specific mu-2 isoform of glutathione S-transferases (*GSTM2*) was up-regulated in the abnormal samples, particularly in the heavy groups. The genes encoding myogenic differentiation (*MYOD1*) and myosin light chain kinase (*MYLK*) exhibited similar expression pattern, of which medium-WS and heavy-WS significantly increased compared to non-defective whereas expression in heavy-WS+WB was not different from either non-defective or WS-affected group. The greatest and the lowest levels of calpain-3 (*CAPN3*) and delta-sarcoglycan (*SCGD*) were observed in heavy-WS and heavy-WS+WB, respectively. Based on micrographs, the abnormal muscles primarily comprised fibers with cross-sectional areas ranging from 2,000 to 3,000 μm^2. Despite induced glycolysis at the transcriptional level, lower stored glycogen in the abnormal muscles corresponded with the reduced lactate and higher pH within their meats. The findings

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Full length article

Effects of *Bacillus aryabhattai* TBRC8450 on vibriosis resistance and immune enhancement in Pacific white shrimp, *Litopenaeus vannamei*

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ABSTRACT

The use of probiotics in aquaculture is a practical alternative to promote animal health and disease prevention. Meanwhile, this practice can also reduce the use of prophylactic antibiotics. The purpose of this study was to identify candidate probiotics that could control pathogen populations in host's gastrointestinal (GI) tract and stimulate host immunity in shrimp aquaculture. *Bacillus aryabhattai* TBRC8450, a bacterial strain isolated from the environment in a shrimp farm, has an antimicrobial activity against many pathogenic strains of *Vibrio harveyi* and *V. parahaemolyticus*. Supplementation of *B. aryabhattai* to Pacific white shrimp (*Litopenaeus vannamei*) not only decreased the abundance of *Vibrio* populations, but also shifted the bacterial community in the shrimp GI tract. We found that supplementation of *B. aryabhattai* triggered shrimp innate immunity and antioxidant activities. mRNA expression of genes encoding microbial peptides and antioxidant enzymes, including C-type lectin, penaeidin-3, heat shock protein 60, thioredoxin, and ferritin, was significantly upregulated in the hepatopancreas of shrimp fed *B. aryabhattai*. Furthermore, phenoloxidase activity in the hemocytes and the total antioxidant activity in the plasma were increased, indicating enhanced immune and antioxidant responses at the systemic level. In contrast, supplementation of *B. aryabhattai* had no effect on the total hemocyte count and superoxide dismutase activity in the plasma and hepatopancreas. Importantly, a pathogen challenge test using *V. harveyi* 1562 showed a significant increase in survival rates of shrimp fed *B. aryabhattai* compared to the control group. Our findings suggest that *B. aryabhattai* TBRC8450 can likely be used as a probiotic to reduce the population of *V. harveyi* in the shrimp GI tract and to enhance shrimp innate immunity and antioxidant capacity for vibriosis resistance in shrimp aquaculture.

1. Introduction

Shrimp aquaculture is a rapidly growing industry with a total production in million metric tons each year [1]. *L. vannamei*, known as Pacific white shrimp, is the most dominant species in shrimp world productions [1]. Pacific white shrimp are predominantly produced from aquaculture in China and Southeast Asian countries [1]. *L. vannamei* originally cultivated in the Pacific coast of the Central and South America was introduced into Asia due to its high growth performance and disease resistance [2]. However, after a few decades of massive cultivation, Pacific white shrimp became susceptible to many disease outbreaks [3–5]. As the result, the production of Pacific white shrimp has decreased dramatically, leading to massive decline in economic incomes.

Infectious diseases resulting from *Vibrio* spp. have been a major burden in shrimp aquaculture worldwide [6–8]. Although *Vibrio* spp. are considered as commensal bacteria in marine animals. Some strains of *V. harveyi* and *V. parahaemolyticus* have been known to cause serious shrimp outbreaks [9–12]. Infection of *V. harveyi* causes luminous vibriosis, white tail disease, and bright-red syndrome, leading to massive mortality in shrimp hatcheries [13]. On the other hand, *V. parahaemolyticus* is a causative pathogen of acute hepatopancreatic necrosis

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Suppression of white feces syndrome in Pacific white shrimp, *Litopenaeus vannamei*, using hen egg white lysozyme

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Immune response
Antimicrobial activity
Vibrio
Pacific white shrimp
White feces syndrome

ABSTRACT

White feces syndrome (WFS) is one of the major constraints for shrimp cultivation. Although the pathogen causing WFS remains largely unknown, WFS has been associated with an increase in vibrio abundances in shrimp haemolymph and intestine. We demonstrated that hen egg white lysozyme (HEWL) inhibited in vitro growth of *Vibrio* spp. including *V. alginolyticus*, *V. harveyi*, and *V. parahaemolyticus*. To alleviate shrimp losses from WFS, HEWL was supplemented into feed at 0.005, 0.025, 0.125, and 0.625 g/kg diet. Supplementation at 0.125 (HEWL0.125) and 0.625 (HEWL0.625) g/kg diet retained the antimicrobial activity under the cultivation water. Both of the supplemental levels also showed a significant antimicrobial activity and reduction in vibrio richness in shrimp gastrointestinal tract. We further analyzed the effect of HEWL supplementation on the expression of immune and antioxidant related genes in hepatopancreas. HEWL0.125 substantially up-regulated the expression of prophenoloxidase, serine proteinase, superoxide dismutase, thioredoxin, and ferritin. Growth performance analysis of weight gain, average daily gain (ADG), feed conversion ratio, and survival rate was also determined, but there were no differences in those parameters. When shrimp were challenged with a pathogenic strain of *V. harveyi*, we observed the greater survival rate in HEWL0.125 than that of the control group (66.67% vs. 16.67%). Importantly, the effect of HEWL0.125 on WFS was evaluated in a shrimp farm. The incidence of WFS was disappeared without occurrence in shrimp fed HEWL0.125. As a result, the survival and ADG were improved significantly. In conclusion, dietary supplementation of HEWL0.125 could inhibit vibrio growth and stimulate immune- and antioxidant-related gene expression leading to resistance against WFS in shrimp.

1. Introduction

Pacific white shrimp, *Litopenaeus vannamei*, is one of the most cultivated penaeids in the world (The Fish Site, 2018). However, infection diseases including luminous vibriosis, acute hepatopancreatic necrosis syndrome (AHPND), and white feces syndrome (WFS) have deteriorated shrimp cultivation. WFS outbreaks have been frequently reported in Thailand which are responsible for a 10 to 15% loss in shrimp production (Srisuvan Iam et al., 2014). The disease can be detected by the presence of white stringy feces (Srisuvan Iam et al., 2014; Morales, 2015). Infected shrimp exhibit loose exoskeleton and pale hepatopancreas and intestine. As a consequence, the survival rate and growth performance of shrimp were declined dramatically. *Enterocytozoon hepatopenaei* (EHP), a microsporidian parasite in shrimp hepatopancreas (Tangprasittipap et al., 2013), has been proposed as the cause of WFS (Ha et al., 2013; Tang et al., 2016). WFS shrimp collected from the fields largely showed EHP infection. Nevertheless, experimentally infected with EHP, shrimp failed to demonstrate WFS symptoms (Tangprasittipap et al., 2013). An elevation in vibrio richness was also reported in WFS shrimp (Sombon et al., 2012). The number of vibrios including *V. vulnificus*, *V. fluvialis*, *V. parahaemolyticus*, *V. alginolyticus*, *V. mimicus*, *V. cholerae* and *V. damsalae* in haemolymph and intestine of WFS shrimp were two-fold higher than that of healthy shrimp (Sombon et al., 2012). It was therefore speculated that vibrio infection

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Collection: Discovery of novel bacteria isolated from Thai fermented food products

Lentibacillus juripiscarius (Namwong et. al., 2005)

2005-2007

Halococcus thailandensis (Namwong et. al., 2007)

Natrinema gari (Tapinkae et al., 2008)

2008-2009

Salinivibrio siamensis (Chamroensaksri et. al., 2009)

Bacillus siamensis (Sumpavapol et. al., 2010)

2010-2011

Gracilibacillus thailandensis (Chamroensaksri et. al., 2010)

Idiomarina piscisalsi (Sitdhipol et.al., 2013)

2013-2016

Lactobacillus ixorae *(Techo et al., 2016)*

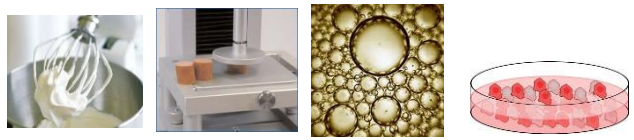
Lentibacillus lipolyticus (Daroonpunt et.al., 2019)

2019-2020

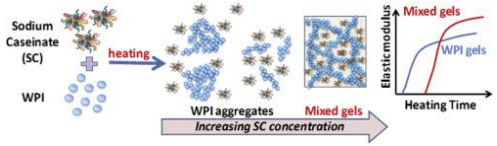
Core capability & Technology platform: Protein & Peptide Technology

Industrial interest

Protein/Peptide Functionality

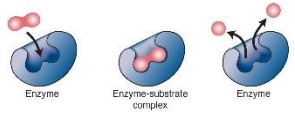


Food Matrix Interaction



Alternative Protein Sources

Enzyme-aided food processing



Core capability

Physical & Protein Functionality Analysis

- Texture analysis
- Viscosity
- Solubility
- Food structure
- Gelling, foaming & emulsifying properties

Chemical Analysis

- Total protein
- Amino acid profile
- Enzyme activity
- Degree of hydrolysis
- Peptide analysis
- Enzymatic screening

Bioaccesibility & Bioavailability & Biological Activity

- Dynamic *in vitro* gastrointestinal model (TinyTIM®)
- Cell-based Assay

Food Processing & Protein Purification

- Protein purification
- Protein modification
- Thermal process

Collaboration & network

OVF ไอวีเอฟ · DMF THAILAND · TANTAWAN ทานตะวัน · yamamori · SUNFOOD · AST·ASAH · SQUID BRAND · BETAGRO · MTEC a member of NSTDA · BIOTEC a member of NSTDA

Core Capability & Technology Platform: Starter Technology

Industrial interest | **Core capability** | **Collaboration & network**

Fermented Foods and seasoning

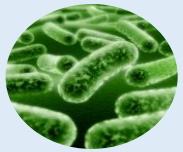
- Process control & reliability
- Consistent quality
- Safety
- Value-added products

Fermented Feed

- Shelf-life extension
- high-quality feed

Screening technology of potential microbes

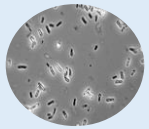
Lactic acid bacteria



L. plantarum

Acetic acid bacteria

Bacillus



Bacillus spp.

Culture optimization

Scale up

เอแอนด์พี ออร์ชาร์ด (A&P Orchard)

MicroINNOVATE

Pigeon Brand

สหกรณ์โคนม

BIOTEC a member of NSTDA

กรมปศุสัตว์

Platform Technology for Probiotics

Industrial interest
- Probiotic specification

Anti-ETEC

In vitro
- 10 strains for porcine ETEC
- 3 strains for human ETEC

Screening platform

Anti-inflammation

Cell line model
- monocyte
- macrophage

7 strains for porcine ETEC
3 strains for human ETEC

SCFA production
- *Bifidobacterium thermophilum* IFBT1159
- *Lactobacillus reuteri* IFBT1687

Limitation
- Animal trials

Probiotic candidates

Safety evaluation

(WGS analysis)
- *Lactobacillus plantarum*
- *Bacillus velezensis*
- *Bifidobacterium animalis*

Production
- Optimization
- Scale up

Animal trial

Food and Feed applications

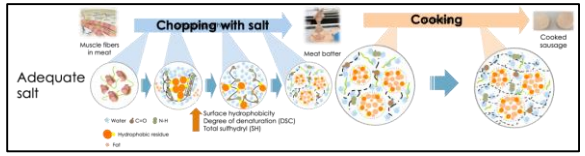
Collaboration network
- Food industry
- Feed industry
- Diary industry

Core capability & Technology platform: Meat Science & Food Innovation

Industrial interest

Meat Defects: White striping (WS) & wooden breast (WB) myopathies

Quality improvement of meat products



Value-added food products

Plant-based meat/Foods for special needs

Core capability

Gene Expression Analysis

- Real-time PCR and digital droplet PCR techniques
- Gene expression analysis in muscle tissue

Physicochemical Analysis

- Meat texture and color analysis
- Chemical & biochemical analysis in muscle meat
- Muscle structure and composition
- Muscle & meat quality
- Meat defect characterization

Meat Product Processing and Formulation

- Conversion of muscle to meat
- Meat product processing (ea. tumbling, emulsifying, and retorting)
- Meat-food ingredient interactions (ea. salt and fat reduction)

Collaboration & Network

MTEC a member of NSTDA

Prince of Songkla University

จุฬาลงกรณ์มหาวิทยาลัย Chulalongkorn University

มหาวิทยาลัยเชียงใหม่

มหาวิทยาลัยธรรมศาสตร์ THAMMASAT UNIVERSITY

มหาวิทยาลัยเกษตรศาสตร์

UNIVERSITY of GUELPH

ALMA MATER STUDIORUM A.D. 1088

Mindset and Strategy

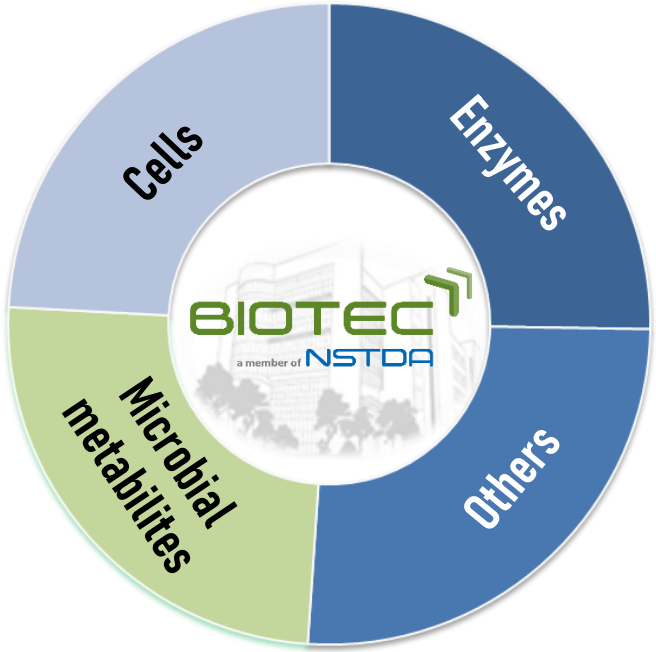
- Researcher … Solution Provider
- Laboratory scale … Commercial scale
- Customer … Team and Strategic Partner

Tools and Strategies for Increasing Competitiveness of Food and Feed Industry

To use Thai bioresources to create innovative solution that can increase competitiveness and sustainability of Thai industries

- **Food Starters**
- **Probiotics**
- **New expression system**

- **Natural antimicrobials**



- **Specialty enzymes**
- **Biotranformation**

- **Fermented products**
- **Process optimization**
- **Process improvement**

“SOLUTION PROVIDER”

Cost Reduction | Import Substitution | Process Scale-up | Novel Products | Value Creation

R-D-I-M-C Pipeline of Beneficial Microbes

Screening

*Primary
**Secondary
***Simulated condition

Strain & Product Characterization

Strain identification
In vitro assay
In vivo assays

- Upstream processing (Fermentation)
- Downstream processing (Drying Formulation)
- Scaling-up
- Product development (Incresed stability to heat and pH, viability)
- Assessment of techno-economic feasibility

Efficacy & Safety testings

Animal studies

Clinical studies

Industrial Production & Product registration & Commercialization

Starter culture

Probiotic product

Discovery of novel antimicrobial peptides and Development of industrial-scale production of lysozyme peptide under GMP standard

Pain point and needs

- Development of antimicrobial resistant (AMR) bacteria against chemical preservatives and antibiotics
- Demand for safe natural antimicrobial agents
- Antimicrobial peptides derived from food and GRAS bacteria are promising alternatives.

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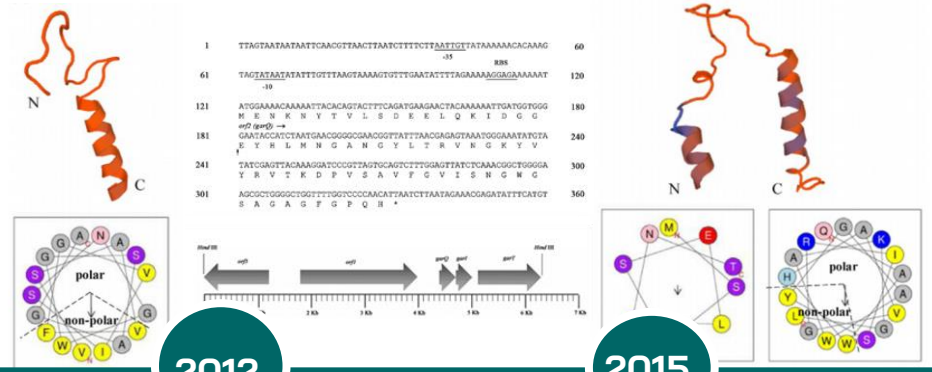
AMPs discovery, characterization and utilization platform

Novel AMPs from microbes



Food protein derived AMPs

2009

2012

- **Garviaecin Q**

2015

- **Bacteriocin 7293A and B**

2018

- **eLysoyzme T1 and eLysozyme T2**
  - Broaden antimicrobial spectrum of lysozyme to inhibit Gram-negative bacteria

2020

- **5 novel AMPs from eLysozyme**
- **Hydrolyzed egg shell membrane**
- **Anti-*Streptococcus suis* peptide**
- **Anti-*Helicobacter pylori* peptide**

Value addition: Antimicrobial agents from hen egg white protein (eLysozyme™, eLYS-T1, eLYS-T2)

2015

Lab scale production of antimicrobial agents from hen egg white protein (Lysozyme)
(BIOTEC, In-house project)

2016

Trade secret – Production of antimicrobial agents from hen egg white protein (eLYS-T1)

2017

Trade secret – Antimicrobial formulation of hen egg white protein with enhanced antimicrobial activity (eLYS-T2) for shrimp aquaculture

2018

- Industrial scale production of eLYS-T1 and eLYS- T2
- Field trials of eLYS-T1 for shelf life extension of pasteurized liquid whole egg
- **Field trials of eLYS-T2** for control of white feces syndrome in white shrimp

2019

eLYS-T2 product launch – B2B from OVF to TFM

2020

Pilot scale production of antimicrobial agents from hen egg white protein
- eLYS-T1 for food
- eLYS-T2 for animal feed

Licensing - Production of antimicrobial agents from hen egg white protein (eLYS-T1)

- MOU for IP management of eLYS-T2
- FDA certificate for eLYS production line
- FDA certificate for eLYS-T1 as food additive
- DOF certificate for eLYS-T2 as feed supplement

2021

Development of eLYS for public health and medical uses (Anti-hypertension, *Anti-Helicobacter pylori*)

eLysozyme™

≥ 50,000 THB/kg

Lysozyme

3,000- 4,000 THB/kg

R-D-I-M-C Antimicrobials Development Platform

Sources

Bacterial derived AMPs
- Activity based screening
- High through-put screening

Bacteriophage
- Screening and identification
- Production and purification

Food derived AMPs
- Source identification
- Peptide cutting simulation
- 3D, pI, hydrophobic prediction
- Membrane insertion prediction
- Optimization of hydrolysing process
- Peptide identification

Other natural antimicrobials
- Extraction, Purification, Identification

Characterization

Characterization
- Antimicrobial spectrum
- Stability in pH, temp, solvents, specific environment
- Mode of action
- Induction of bacterial resistant
- Cytotoxicity
- Allergenicity
- Other biological activities (anti-ACE activity, antioxidant, anti-cancer, anti-inflammatory, Vasorelaxation)

Product formulation

Formulation
- TOP and DDS
- Design of application
- Review of FDA/Fisheries/DLD regulation
- Design of combination
- Antimicrobial synergy testing
- Establish antimicrobial formulation
- Formulation testing in lab
- Safety evaluation: Cytotoxicity, allergenicity, induction of bacterial resistant of the formulation
- Lab prototype

Industrial applications

Food application
- Direct addition/Food packaging application
- Field/industrial prototype

Live stock, aquaculture, horticulture
- Design of dosage and usage
- Field test
- Field prototype

Personal care/cosmetics/ pharmaceutical
- Design of dosage and usage
- Field test
- Field prototype

Production & Compliance

Up-scaling
- Pilot scale
- Industrial scale

Cost structure analysis

GMP plant certification
- Plant design
- Production trial
- SOP and QC
- Documentation
- Registration

Product certification
- CoA
- MSDS
- Documentation
- Product registration

- ตอบสนองต่อการเปลี่ยนแปลง ที่ไม่แน่นอน ได้อย่างรวดเร็ว
- สร้างความเข้มแข็งจากภายใน บนรากฐานของทรัพยากรที่มี อย่างยั่งยืน

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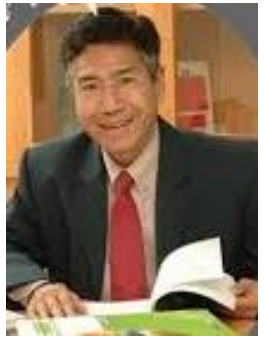
ดร.รุจ วัลยะเสวี


ดร.กัญญวิมว์ กีรติกร


ศ.ดร.สมบูรณ์ ธนาศุภวัฒน์


ศ.ดร.สุทธวัฒน์ เบญจกุล

Team + Students+ Collaborators + Funding Sources

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