Frontispiece

Rihaakuru

Control of Histamine in *Rihaakuru*: Emerging Approaches

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List of published and submitted manuscripts and presentations

Peer reviewed publications

1. Naila, A., Flint, S., Fletcher, G., Bremer, P., & Meerdink, G. (2010). Control of Biogenic Amines in Food-Existing and Emerging Approaches. *Journal of Food Science*, *75*(7), R139-R150.

2. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., & Meerdink, G. (2011a). Chemistry and microbiology of traditional *Rihaakuru* (fish paste) from the Maldives. *International Journal of Food Sciences and Nutrition*, *62*(2), 139-147.

3. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., & Meerdink, G. (2011b). Biogenic amines and potential histamine - Forming bacteria in *Rihaakuru* (a cooked fish paste). *Food Chemistry*, *128*(2), 479-484.

4. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., & Morton, R. H. (2011c). Degradation of histamine in tuna soup by diamine oxidase (DAO). In: *Food and Environment*, vol. 152 (p. 103-112). England, UK: WIT press.

5. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., (Submitted). Histamine stability in Rihaakuru at -80°C, 4°C and 30°C. Food Chemistry.

6. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., (Submitted). Histamine degradation by diamine oxidase, Lactobacillus and Vergibacillus halodonitrificans Nai18. Food Chemistry.

7. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., (Submitted). Prediction of the amount and rate of histamine degradation by diamine oxidase (DAO). Food Chemistry.

Conference presentations

Oral presentations

1. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2008). Histamine production during the manufacture of a fish paste product from the Maldives. New Zealand Microbiological Society (NZMS) Conference: Germs and Genomes in the garden city, 18-21 November, University of Canterbury, Christchurch, New Zealand.

2. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2010). Histamine stability in *Rihaakuru.* New Zealand Microbiological Society (NZMS) and New Zealand Society for Biochemistry & Molecular Biology (SBMB) Conference: small things and big ideas, 30 November- 3 December, The University of Auckland, New Zealand.

3. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., & Morton, R. H. (2011). Degradation of histamine in tuna soup by diamine oxidase (DAO). First International Conference on Food and Environment- The quest for a sustainable future, 21-23 June, New Forest, UK.

4. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2011). Degrading histamine in *Rihaakuru*: An emerging approach. NZMS Annual Conference, 23-25 November, Palmerston North, New Zealand.

Poster presentations

1. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2009). Natural microflora of a fish paste product (*Rihaakuru*) from the Maldives. New Zealand Institute of Food Science & Technology (NZIFST) Conference: food elements- putting the pieces together, 23-25 June, Christchurch Convention Centre, Christchurch, New Zealand.

2. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2011). Histamine degradation by bacteria and diamine oxidase. Society for Applied Microbiology (sfam) summer conference, 4-7 July, Dublin, Ireland.

3. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., & Morton, R. H. (2011). Degradation of histamine in a model system by diamine oxidase (DAO). Securing Global Food Safety conference-14th Australian Food Microbiology Conference & 2nd IAFP Asia Pacific Symposium on Food Safety, 26-28 September, Melbourne, Australia.

4. Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G., & Morton, R. H. (2011). Modelling the degradation of histamine in tuna soup by diamine oxidase (DAO). NZMS Annual Conference, 23-25 November, Palmerston North, New Zealand.

Other publications

Naila, A., Flint, S., Fletcher, G. C., Bremer, P. J., Meerdink, G. (2009). The development and control of histamine production in a fish paste product (*Rihaakuru*) from the Maldives. Food New Zealand, F-files, p. 19.

Abstract

Rihaakuru is a cooked fish paste from the Maldives, consumed as a condiment with rice and other food. The product is unique to the Maldives and there is no information on the composition, characteristics and safety of this product. Histamine contamination has been suspected due to symptoms sometimes seen following consumption. This research established that *Rihaakuru* is a nutritious and shelf-stable product. *Rihaakuru* is generally produced from poor quality fish therefore presence of biogenic amines was suspected. This study confirmed that *Rihaakuru* contained up to ten different biogenic amines, with histamine in excess of 500 ppm. This may cause histamine poisoning with symptoms such as skin rashes, vomiting and fever. The product examined in this study contained a few weak histamine forming bacteria. Most of the histamine is likely to be produced by bacteria in the raw fish. These bacteria are likely to die during the manufacture of *Rihaakuru.* Histamine in *Rihaakuru* decreased by 30-70% during storage at -80°C, 4°C and 30°C for 10 months. This showed that the histamine hazard in *Rihaakuru* is unlikely to increase and may decrease during long term storage. Traditional control of histamine in food is through refrigeration of raw material. In the case of the fish used to manufacture *Rihaakuru,* refrigeration is not available or limited. Histamine oxidizing bacteria and enzymes were identified as emerging approaches to degrade pre-formed histamine. Histamine oxidizing bacteria (*Lactobacillus sakei* [AGR 37, AGR 46, Lb 706] and *Vergibacillus halodonitrificans* Nai18) tested in this study degraded histamine by 30-50%. The histamine oxidizing enzyme, diamine oxidase (DAO) completely degraded 500 mg/L of histamine at pH 6 and salt 1% in buffer and in the tuna soup used to manufacture Rihaakuru. A regression model was developed that predicted the rate and amount of histamine removal by DAO under varied pH and salt concentration. This model may be used to determine conditions that will reduce histamine in other foods that have similar characteristics to the tuna soup used to manufacture *Rihaakuru*.

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List of Abbreviations

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CCD	central composite design
CHD	coronary heart disease
CHO	carbohydrates
DAO	diamine oxidase
DHA	docosahexaenoic acid
DNA	deoxyribonucleic acid
DPA	docosapentaenoic acid
DSMZ	Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH
EDTA	ethylene diamine tetra acetic acid
EPA	eicosapentaenoic acid
ETE	eicosatrienoic acid
FDA	Food and Drug Administration
FID	Flame Ionization Detector
GAM	Gifu Anaerobic Medium broth
GC	gas chromatography
GDL	glucono-delta-lactone
GE	Gross Energy
HDC	Hisitidine Decarboxylase
HHP	high hydrostatic pressure
HPLC	high performance liquid chromatography
ICMSF	International Commission on Microbiological Specification for Foods
MAOI	monoamine oxidase inhibitors
MAP	modified atmosphere packaging
MPN	most probable number
MRS	deMan, Rogosa and Sharpe broth
MS	mass-spectroscopy
NOAEL	no observed adverse effect level
NZAID	New Zealand Agency for International Development
NZDS	New Zealand Development Scholarship

NZIFST	New Zealand Institute of Food Science and Technology
NZMS	New Zealand Microbiological Society
PCR	polymerase chain reaction
PUFA	polyunsaturated fatty acids
RDI	recommended daily intake
rDNA	Ribosomal DNA
RSM	response surface model
SBMB	New Zealand Society for Biochemistry and Molecular Biology
sfam	Society for Applied Microbiology
TCA	trichloroacetic acid
TDF	Total Dietary Fibre
TLC	thin layer chromatography
TMAH	tetramethylammonium hydroxide
TSA	trypticase soy agar
TSB	trypticase soy broth
TSBH	histidine tripticase soy broth
UHT	ultra high temperature
USA	United States of America
USDA	United States Department of Agriculture
UV	ultra-violet
WHO	World Health Organization

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