

**STUDIES ON INSECT PESTS OF RAGI VALUE ADDED
PRODUCTS WITH SPECIAL REFERENCE TO *Corcyra*
cephalonica STANTON**

LATHA, H. C.

PAK 8088

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU – 560 065
2010**

**STUDIES ON INSECT PESTS OF RAGI VALUE ADDED
PRODUCTS WITH SPECIAL REFERENCE TO *Corcyra
cephalonica* STAINTON**

LATHA, H.C.

PAK 8088

*Thesis submitted to the
University of Agricultural Sciences, Bengaluru
in partial fulfillment of the requirements
for the award of the degree*

Master of Science (Agriculture)

in

Agricultural Entomology

BENGALURU

JULY, 2010

Affectionately Dedicated

To

My Beloved Parents

Brothers

and Sister

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU-560 065**

CERTIFICATE

This is to certify that the thesis entitled “**Studies on insect pests of ragi value added products with special reference to *Corcyra cephalonica* Stainton**” submitted by **Ms. Latha, H.C.**, in partial fulfillment of the requirements for award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** to the University of Agricultural Sciences, Bengaluru, is a record of *bonafide* research work done by her during the period of her study in this university under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
July, 2010

(P. S. JAGADISH)
Major Advisor

Approved by:

CHAIRMAN : _____
(P. S. JAGADISH)

MEMBERS : 1. _____
(C. T. ASHOK KUMAR)

2. _____
(A. NAGARAJA)

3. _____
(JAYARAME GOWDA)

4. _____
(NEELU NANGIA)

ACKNOWLEDGEMENT

*I would like to express my deep sense of gratitude and indebtedness to **Dr. P. S. Jagadish**, Professor, senior Entomologist and Technical project leader, , AICRP on small millets, UAS, Bengaluru, for his inspiring guidance, valuable suggestions, generous help and encouragement throughout my study period.*

*It gives me an immense pleasure to thank, **Dr. C. T. Ashok Kumar**, Professor, Department of Agricultural Entomology, for his peerless guidance, incessant inspiration, constructive criticisms, and scholarly advice, sustained encouragement and for his valuable help for successful completion of my thesis.*

*I wish to express heart felt thanks to **Dr. A. Nagaraja**, Pathologist and Technical project leader, AICSMIP University of Agricultural Science, G.K.V.K., Bengaluru for his valuable advice as Advisory Committee Member.*

*My sincere thanks to **Dr. Jayarame Gowda**, Geneticist and Technical project leader, AICSMIP, University of Agricultural Science, G.K.V.K., Bengaluru for his encouragement and valuable suggestions throughout my research period.*

*I profusely thank **Dr. Neelu Nangia**, professor, Department of Sericulture, University of Agricultural Science, G.K.V.K., Bengaluru, for her valuable and timely guidance during my course of study.*

*I thank, **Dr. A. K. Chakravarthy**, Professor and Head and all the professors of Department of Agricultural Entomology, University of Agricultural Science, G.K.V.K., Bengaluru, for their moral support during my study.*

*I thank to **DR. C. A. Viraktmath sir**, College of Agriculture, UAS, GKVK, Bangalore for being supportive and helpful while I carried out my research work.*

*I am grateful and thankful to **Prashant Mohanraj, Bharathi dasan**, NBAII, Hebbal for their guidance and helpness during my study degree programme.*

Thanks to all the supporting staff of the department of Agricultural Entomology for their assistance during various stages of the study.

*I owe my success to my Father **Mr. Chikkasiddaiah** and my Mother **Mrs. Akkamahadevamma**, my sister, **Ms. Sowmya. H. C** and my brothers **Mr. Nagendran. H. C** and **Hari. H. C** whose abiding love, affection, encouragement and moral support throughout my study period without which I would not have achieved this goal.*

*My sincere and special thanks to Senior **Mr. Shivaraju** for his kindness, help, encouragement and co-operation rendered during course of study.*

*I also thank to **Shankarmurthy sir, Reddy sir, Yaswanth sir** and **Nirmala akka** for their valuable guidelines and help during my study period.*

*I will be failing in my duty if I do not acknowledge the help rendered by my friends by one way or the other. Specially, I am very much thankful to **Arpitha akka, Brusli, Latha, Jini, Mallikarjun, Lavanya, Savitha, Geeta D, Shilpa akka, Mamathalakshmi, Teemu, Nagamma, Pavithra and Ranjita** who has helped me in all aspects of my research work and all my classmates and senior freinds who have helped me in one way or the other for which I am ever grateful to them.*

Bengaluru

Date:

(LATHA. H.C)

**Studies on Insect Pests of Ragi Value Added Products with Special Reference to
Corcyra Cephalonica Stainton.**

ABSTRACT

Finger millet, *Eleusine corcana* (L.) is a small millet and quick growing crop, particularly suited to a dry continental climate. Finger millet value added products enhances the bioavailability of nutrients, but also improves the overall nutritional quality of grains. Diversification of diet is necessary to overcome the nutritional situation in the country. Study was conducted on *C. cephalonica* to record the insect pests of ragi value added products and their incidence, biology of *C. cephalonica* and shelflife of ragi value added products. The present study has brought to light five species of insect pests viz., *Sitophilus oryzae*, *Corcyra cephalonica*, *Callosobruchus maculatus*, *Tribolium castaneum* and *Lasioderma serricorne* feeding on ragi value added products at different localities. The incidence of all insects was maximum during July to December and minimum during January to June at all locations on all the ragi value added products except on chakali. The incubation period of on hurihittu was 4.3 days. The mean duration of six instar was 5.7, 8.5, 5.6, 6.7, 4.3 and 9.8 days respectively. Total larval period was 37 to 45 days. The pupal period was 11.92 days. The adult longevity was 7.4 and 11.6 days in mated males and females respectively. *C. cephalonca* took 52 to 67 days to complete development on Hurihittu. The mating process took 55 to 120 minutes, pre-ovipositional period was 1 to 2 days. The fecundity ranged from 254 to 392 eggs, oviposition period lasted 5 to 8 days. Influence of different hosts on the biology of *C. cephalonica*. The shortest total developmental period of 38.20 days on Hurihittu and longest of 49.07 days on Sandige. Shelf life of ragi value added products which is stored in the cloth bag was less, whereas products stored in steel container shows longer shelflife.

Signature of the Student
(Latha, H.C.)

Signature of the Major Advisor
(P.S. JAGADISH)

**gÁV AiÄÄ^a AiË®^a ÄçüðvÀ GvÀà£ÀßUA½UE ©Ä¼ÄÄ^a QÄIUÄ¼ÄÄ,
 «±ÉÄµÄ^a ÁV PÁ¹ðgÁ^a ¶sÀ-ÉÆÄ±PÄ ÉÖÄ£l£tUE ÀAŞAçü¹zÀ
 CzsÄâAiÄÄ£ÄUA¼ÄÄ.
 ÁgÄA±À**

gÁV, J®Æ¹£Á PÉÆgÁPÁ£Á(°) MAzÄÄ ¨ÉÄUA£É ¨É¼ÉAiÄÄÄ^aÀ vÀÈt
 zsÁ£ÄÄ ¨É¼ÉAiÄÄVzÄÄÝ Mt°^aÉ ¶ÄæzÉÄ±ÁPÉÌ
 ÀÆPÄÜ^a ÁVgÄÄvÀÛzÉ.gÁV AiÄÄ^a AiË®^a ÄçüðvÀ GvÀà£ÀßUA¼ÄÄ
 ¥ÉÆÄµÀPÄA±ÄUA¼ÄÄ eÉÉ«PÄ ®^asÀävÉAiÄÄ£ÄÄß °ÉaÑ,ÄÄ^aÄÄzÀèzÉÄ,
 MmÄÖgÉ ¥ÉÆÄµÀPÄA±ÄUA¼ÄÄ UAÄ^aÄÄÖ^aÄ£ÄÄß^a ÄÈçP,ÄÄvÀÛ^aÉ.
 zÉÄ±ÄzÀ°è£Ä ¥ÉÆÄµÀPÄA±ÄUA¼ÄÄ ¥Äj¹ÜAiÄÄ£ÄÄß Äj¶Är,Ä®Ä D°ÁgÄzÀ°è
 «©ü£ÄßvÉ C^aÄ±ÄÄ^a ÁVgÄÄvÀÛzÉ. gÁV AiÄÄ^a AiË®^a ÄçüðvÀ GvÀà£ÀßUA½UE
 ©Ä¼ÄÄÄ^a QÄIUÄ¼ÄÄ M «±ÉÄµÄ^a ÁV PÁ¹ðgÁ^a ¶sÀ-ÉÆÄ±PÄ zÀ fÄ^aÄ£Ä
 ZÄjvÉæ^a ÄÄvÄÄÛ^a AiË®^a ÄçüðvÀ GvÀà£ÀßUA¼ÄÄ ±ÉÄRgÄuÄ ÄÄÄAiÄÄzÀ
 ŞUEÌ CzsÄâAiÄÄ£Ä PÉÉUEÆ¹ÄÄ^r ÁVvÄÄ.

F CzsÄâAiÄÄ£ÄçzÄ ««zsÄ ÄÜ¼ÄUA¼ÄÄ°è gÁV AiÄÄ^a AiË®^a ÄçüðvÀ
 GvÀà£ÀßUA¼ÄÄ£ÄÄß ÉÉmÉÆlü®i MgÉÉgÉhÄÄ, PÁ¹ðgÁ^a ¶sÀ-ÉÆÄ±PÄ,
 mÉæöÉ^aÉÆÄ°AiÄÄÄ PÄâÉÖÄ±AiÄÄÄ, PÄâ^aÉÆŞÆæPÄi^a AiÄÄPÄÄ-ÉÄlⁱ
^aÄÄvÄÄÛ^a -ÉÄ¹AiÉÆÄqÄ^aÄÄð ÉjPÁ£Éð JAŞ LzÄÄ QÄIUÄ¼ÄÄ
 ¨Äçü,ÄÄ^aÄÄzÄVw½zÄÄ ŞAçzÉ. F J-Äè QÄIUÄ¼ÄÄ dÄ-ÉÉ±AzÄ r,ÉAŞgⁱ ÄgÉUE
 UAjuÄÖ ¥Äæ^aÄiÄtzÄ°è^a ÄÄvÄÄÛ^a d£Ä^aÄj-ÄAzÄ dÆr^aÄgÉUE PÄ±µÄÖ
 ¥Äæ^aÄiÄtzÄ°è J-Äè ÄÜ¼ÄUA¼ÄÄ°è ZÄPÄI° °ÉÆgÄvÄÄ ¥Är¹ EvÄgÉ gÁV AiÄÄ^a
^aAiË®^a ÄçüðvÀ GvÀà£ÀßUA¼ÄÄ£ÄÄß ¨Äçü,ÄÄ^aÄÄzÄV w½zÄÄŞAçzÉ.CQI »nÖ£Ä
 ¥ÄvÄAUÄzÄ^aÉÆmÉÖAiÄÄ ÄgÄ,Äj C^aÄçüAiÄÄÄ 4.3 ç^aÄ,ÄUA¼ÄÄVgÄÄvÀÛzÉ.
 DgÄÄ ««zsÄ^aÄÄj°ÄÄ¼ÄÄUA¼ÄÄ ÄgÄ,Äj C^aÄçüAiÄÄÄ 5.7, 8.5, 5.6, 6.7, 4.3
^aÄÄvÄÄÛ^a 9.8 ç^aÄ,ÄUA¼ÄÄVgÄÄvÀÛzÉ. MIÄÖ^aÄÄj °ÄÄ¼ÄÄ«£Ä C^aÄçüAiÄÄÄ 37
 jAzÄ 45 ç^aÄ,ÄUA¼ÄÄ. QÄlzÄ PÉÆÄ±ÄÄ^aÉÜAiÄÄ C^aÄçü 11.92
 ç^aÄ,ÄUA¼ÄÄVgÄÄvÀÛzÉ. ÄAAiÉÆÄUA °ÉÆAçzÄ UÄAqÄÄ^aÄÄvÄÄÛ^a °ÉÄtÄÜ
 QÄIUÄ¼ÄÄ fÄ«vÄ C^aÄçüAiÄÄÄ C£ÄÄPÄæ^aÄÄ^aÄV 7.4^aÄÄvÄÄÛ^a 11.6
 ç^aÄ,ÄUA¼ÄÄVgÄÄvÀÛzÉ. CQI »nÖ£Ä QÄI^aÄÄ °ÄÄj »nÖ£Ä^aÉÄÄ-É vÄ£Äß ¥ÄÆtð
 fÄ^aÄ£Ä ZÄPÄæ^aÄÄÄV,Ä®Ä 52 jAzÄ 67 ç£ÄUA¼ÄÄ£ÄÄß vÉUEzÄÄ PÉÆArzÉ.

ÄAAiÉÆÄUAzÄ C^aÄçüAiÄÄÄ 55 jAzÄ 120 ±«ÄµÄUA¼ÄÄVzÄÄÝ,
^aÉÆmÉÖ-ÄqÄÄ^aÄÄ ÄÄÄAa£Ä C^aÄçü 1 jAzÄ 2 ç£ÄUA¼ÄÄ. MAzÄÄ °ÉtÄÜ
 ¥ÄvÄAUÄ^aÄÄ ÄÄ^aÄiÄgÄÄ 254 jAzÄ 392^aÉÆmÉÖUA¼ÄÄ£ÄÄß 5 jAzÄ 8
 ç^aÄ,ÄUA¼ÄÄ C^aÄçüAiÄÄ°è EqÄÄvÀÛzÉ. ¨ÉÄgÉ ¨ÉÄgÉ^a AiË®^a ÄçüðvÀ
 GvÀà£ÀßUA¼ÄÄ ¥Äæ^asÄ^aÄÄÄ QÄlzÄ C®^aÄÈçPÄiÄÄ^aÉÄÄ-É ¥ÄjuÄ^aÄÄ
 ©ÄgÄÄ^aÄÄzÉAŞ CzsÄâAiÄÄ£Ä Ä°Ä PÉÉUEÆArzÄÄÝ, °ÄÄj »nÖ£Ä^aÉÄÄ-É Cw
 PÄr^aÉÄ C^aÄçüAiÄÄVgÄÄ^aÄÄzÄÄ (38.20 ç£ÄUA¼ÄÄ)
^aÄÄvÄÄÛ^a ÄArUEAiÄÄ^aÉÄÄ-É Cw °ÉaÑ£Ä C^aÄçüAiÄÄVgÄÄ^aÄÄzÄÄ (49.09
 ç£ÄUA¼ÄÄ) PÄAqÄÄŞAçzÉ. ^aAiË®^a ÄçüðvÀ GvÀà£ÀßUA¼ÄÄ ±ÉÄRgÄuÄ
 C^aÄçüAiÄÄÄ §mÉÖAiÄÄ aÄ®zÄ°è PÄr^aÉÄ ç£ÄUA¼ÄÄVzÄÄÝ, °ÖÄ^aÄ qÄŞâzÄ°è
 °ÉZÄÄÑ ç£ÄUA¼ÄÄVgÄÄvÀÛzÉ.

«zÄÿðAiÄÄ,Ä»^aÄÄÄRÄ,Ä®°ÉUÁgÄgÄÄ

CONTENTS

CHAPTER	TITLE	PAGE NO
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-20
III	MATERIAL AND METHODS	21-25
IV	EXPERIMENTAL RESULTS	26-71
V	DISCUSSION	72-89
VI	SUMMARY	90-93
VII	REFERENCES	94-106

LIST OF TABLES

Table Number	Title	Page Number
1	Insect pests recorded on Ragi value added products during 2009-2010	27
2	Seasonal incidence of <i>S. oryzae</i> on Hurihittu, 2009-10	28
3	Seasonal incidence of <i>S. oryzae</i> on Vermicelli, 2009-10	28
4	Seasonal incidence of <i>S. oryzae</i> on Papad, 2009-10	29
5	Seasonal incidence of <i>S. oryzae</i> on Sandige, 2009-10	29
6	Seasonal incidence of <i>C. cephalonica</i> on Hurihittu, 2009-10	31
7	Seasonal incidence of <i>C. cephalonica</i> on Vermicelli, 2009-10	31
8	Seasonal incidence of <i>C. cephalonica</i> on Papad, 2009-10	32
9	Seasonal incidence of <i>C. cephalonica</i> on Sandige, 2009-10	32
10	Seasonal incidence of <i>C. maculatus</i> on Hurihittu 2009-10	33
11	Seasonal incidence of <i>C. maculatus</i> on Vermicelli, 2009-10	33
12	Seasonal incidence of <i>T. castaneum</i> on Hurihittu, 2009-10	35
13	Seasonal incidence of on <i>T. castaneum</i> Vermicelli, 2009-10	35
14	Seasonal incidence of <i>T. castaneum</i> on Papad2009-10	36
15	Seasonal incidence of <i>Lasioderma serricorne</i> on Hurihittu 2009-10	36
16	Seasonal incidence of <i>Lasioderma serricorne</i> on Vermicelli, 2009-10	38
17	Response of insect pests on ragi value added products, 2009-10	38

18	Duration of different life stages of <i>C. cephalonica</i> on Hurihittu	39
19	Dimensions of head capsule, thorax and body length of different larval instars and pupae	39
20	Duration of different parameters of biology of <i>C. cephalonica</i> on Hurihittu	46
21	Effect of adult feeding on fecundity and longevity of <i>C. cephalonica</i>	46
22	Consumption pattern of Hurihittu by <i>C. cephalonica</i>	48
23	Comparison of different parameters of <i>C. cephalonica</i> on ragi value added products	50
24	Shelf life of Hurihittu against <i>C. cephalonica</i> on different storage structures	53
25	Shelf life of Hurihittu against <i>S. oryzae</i> on different storage structures	54
26	Shelf life of Hurihittu against <i>T. castaneum</i> on different storage structures	56
27	Shelf life of Vermicelli against <i>C. cephalonica</i> on different storage structures	58
28	Shelf life of Vermicelli against <i>S. oryzae</i> on different storage structures	60
29	Shelf life of Vermicelli against <i>T. castaneum</i> on different storage structures	62
30	Shelf life of Papad against <i>C. cephalonica</i> on different storage structures	63
31	Shelf life of Papad against <i>S. oryzae</i> on different storage structures on different storage structures	65
32	Shelf life of Papad against <i>T. castaneum</i> on different storage structures	67
33	Shelf life of Sandige against <i>C. cephalonica</i> on different storage structures	69

34	Shelf life of Sandige against <i>S. oryzae</i> on different storage structures	71
----	--	----

LIST OF FIGURES

Figure Number	Title	Between Pages
1	Seasonal incidence of <i>Sitophilus oryzae</i> on ragi value added products	73-74
2	Seasonal incidence of <i>Corcyra cephalonica</i> on ragi value added products	73-74
3	Seasonal incidence of <i>Callosobruchus maculatus</i> on ragi value added products	74-75
4	Seasonal incidence of <i>T. castaneum</i> on ragi value added products	74-75
5	Seasonal incidence of <i>Lasioderma serricornis</i> on ragi value added products	75-76
6	Comparison of different parameters of <i>C. cephalonica</i> on ragi value added products	80-81
7	Shelf life of Hurihittu against <i>C. cephalonica</i> on different storage structures	82-83
8	Shelf life of Hurihittu against <i>S. oryzae</i> on different storage structures	82-83
9	Shelf life of Hurihittu against <i>T. castaneum</i> on different storage structures	82-83
10	Shelf life of Vermicelli against <i>C. cephalonica</i> on different storage structures	85-86
11	Shelf life of Vermicelli against <i>S. oryzae</i> on different storage structures	85-86
12	Shelf life of Vermicelli against <i>T. castaneum</i> on different storage structures	85-86

13	Shelf life of Papad against <i>C. cephalonica</i> on different storage structures	87-88
14	Shelf life of Papad against <i>S. oryzae</i> on different storage structures	87-88
15	Shelf life of Papad against <i>T. castaneum</i> on different storage structures	87-88
16	Shelf life of Sandige against <i>C. cephalonica</i> on different storage structures	88-89
17	Shelf life of Sandige against <i>S. oryzae</i> on different storage structures	88-89

LIST OF PLATES

Plate Number	Title	Between Pages
1	Ragi value added products a. Hurihittu b. Papad c. Vermicelli d. Sandige e. Chakali	21-22
2a	Stock culture of <i>Corcyra cephalonica</i>	23-24
2b	Ovipositional cage for <i>Corcyra cephalonica</i>	23-24
2c	Plastic containers used to study Biology of <i>C. cephalonica</i>	23-24
3	Different storage structures	25-26
4a	<i>Sitophilus oryzae</i>	34-35
4b	<i>Corcyra cephalonica</i>	34-35
4c	<i>Callosobruchus maculatus</i>	34-35
4d	<i>Tribolium castaneum</i>	34-35
4e	<i>Lasioderma serricorne</i>	34-35
5a	Eggs of <i>C. cephalonica</i> Stainton	41-42
5b	First instar larva of <i>C. cephalonica</i> Stainton	41-42
5c	Second instar larva of <i>C. cephalonica</i> Stainton	41-42
5d	Third instar larva of <i>C. cephalonica</i> Stainton	41-42
5e	Fourth instar larva of <i>C. cephalonica</i> Stainton	41-42

5f	Fifth instar larva of <i>C. cephalonica</i> Stainton	41-42
5g	Sixth instar larva of <i>C. cephalonica</i> Stainton	43-44
5h	Pupa of <i>C. cephalonica</i> Stainton	43-44
6	Male and Female of <i>C. cephalonica</i> Stainton	43-44
7	Larva feeding on Hurihittu	43-44

INTRODUCTION

INTRODUCTION

Finger millet, *Eleusine corcana* (L.) is a small millet and quick growing crop, particularly suited to a dry continental climate. This is widely grown in India, Africa, Srilanka, Malaysia, China and Japan, constituting staple food. It is popularly known as ragi in India. In India, during 2009-2010, total production of ragi was 1.89 million tons in an area of 1387.1 ha. In Karnataka, total production was 1394.0 tons during 2009-2010 in an area of 833.0 ha (www.indiastat.com)

Finger millet is a major source of energy and proteins in the diet of rural population. Finger millet protein has well balanced amino acid profile and a good source of methionine, cysteine and lysine (Rai, 2000). These essential amino acids provide special benefit to those who depend on plant food for their nourishment. The fat from finger millet contains higher proportion of unsaturated fatty acids and supply essential fatty acids. Finger millet is especially rich in Ca, containing as much as 344 mg/100g. Relatively higher proportion of CHO which is in the form of non-starchy polysaccharides and dietary fiber of finger millet with low fat provide several nutritional and physiological benefits viz, hypocholesterolemic, hypoglycemic effect by slow release of glucose to the blood stream during digestion and reduce transit time. It is of interest to note that lower incidence of hyperglycemia (diabetes), cardiovascular diseases, duodenal ulcer etc., are reported among regular millet consumers (Rai, 2000).

Finger millet value added products enhances the bioavailability of nutrients, but also improves the overall nutritional quality of grains. It is a storehouse of digestive enzymes and low molecular weight carbohydrates reduces the water holding capacities of foods. Consequently, the liquid food will be low in dietary bulk but high in nutrient density. Diversification of diet is necessary to overcome the nutritional situation in the country. More so micronutrient malnutrition is affecting the working capacities and also the serious consequences like growth deficits, child deaths, cognitive development etc.

People are now becoming very health conscious and would like to consume foods containing high fiber, low fat and other protective nutrients. Some of the ragi value added products made from millets contain high fiber content and low fat and expected to find a place among health foods. Enrichment of value added products with proteins, vitamins, minerals and other vegetable sources such as pulses and soybeans further increases its nutritive value. Some of the value added products are Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku).

The finger millet vermicelli on analysis contains nearly 18 per cent protein and negligible amount of fat, carbohydrate content of 206 Kcal, calcium and iron content being 214 mg and 5 mg respectively. Low calorie ragi vermicelli is very much advisable healthy food for diabetic people.

Papad having moisture of 4.8 g, protein 8.6 g, fat is 1.4 g, ash 5.3 g, crude fiber 1.8 g, carbohydrate 78 g, energy 35 g Kcal, calcium 157 mg, phosphorus 265 mg and iron 5.4 mg. It is also very good for diabetic patients.

About 15 % of the grains stored after each harvest is believed to be lost due to the ravages of rats, insects, mites and other microbial agents (Walter, 1971). Neelakanthan (1972) claimed that the annual loss of food grains in the Indian Godowns as a result of insect infestation was about 5 million tons.

In another loss estimation study, Purandaram (1976) observed that 6.58% of the total losses estimated were due to the faulty storage of grains leading to damage by insects (2.55%), rodents (2.5%), birds (0.85%) and moisture (0.68%). Among the primary pests known to cause appreciable damage and loss of stored grains, the rice meal moth, *Corcyra cephalonica* Stainton has become one of the most serious and destructive pest of all stored cereals and millets, pulses and oilseeds (Ayyar, 1934).

A global survey conducted by the Food and Agriculture Organization (FAO) revealed 10 per cent of grain loss in storage which equals to 13 million tones due to

infestation of storage pests, pathogens and rodents etc., and also considered *Corcyra cephalonica* to be a major pest of wheat, rice and millets in India (Champ and Dyte, 1977), and was rated as one of the major pest of stored cereals in the tropics and subtropics.

Finger millet grains are commonly infested by store pest like the rice meal moth *Corcyra cephalonica* Stainton which is also known to infest rice, wheat, maize, sorghum and other millets etc., oilseeds like groundnut, sesame and oilcakes, cottonseed and pulses like redgram, blackgram, cowpea, etc., with a wide distribution in tropical and subtropical countries (Ayyar, 1934).

There is a report of insect pests on ragi but there have been no reports of pest occurrence on the value added products, and since these products are becoming popular it was felt essential to workout the incidence of insect pests and basic studies of *Corcyra cephalonica* as a pest on these products and shelf life of ragi value added products which would pave way in developing a management programme.

In view of this a study was undertaken with the following objectives,

- a. To record the incidence of insect pests occurring on stored ragi value added products.
- b. To study the biology of *Corcyra cephalonica* on ragi value added products.
- c. To study the shelf life of ragi value added products.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Literature pertaining to insect pests of ragi value added products, biology, infestation behaviour of *Corcyra cephalonica* Stainton on ragi value added products and shelf life of ragi value added products is reviewed in the following paragraphs.

2.1 Insect pests of ragi value added products and incidence

Brar *et al.* (1987) surveyed forty three grain markets and different oilseed crushers in Punjab and Chandigarh, and reported *Tribolium castaneum* Herbst and *Oryzaephilus surinamensis* L. were the most common; other species recorded were, *Tenebroides mauritanicus* L., *Corcyra cephalonica* (Stainton), *Trogoderma granarium* (Evert) *Laemophloeus minutes* (Olivier) and *Sitophilus oryzae* L.

Investigations on insect fauna of stored grain insects in Madhya Pradesh revealed that *S. oryzae*, *Rhizopertha dominica* Fabr. and *T. granarium* were the most abundant insects infesting stored wheat. Further, banda storage provided the maximum protection from the pests (Sonelal and Srivastava, 1985).

Surveys were undertaken on the relative abundance of stored grain pests of maize in Karimnagar and Nizamabad districts of Andhra Pradesh. The pests encountered were *Sitophilus zeamais* L., *R. dominica*, *Tribolium castaneum*, *Sitotroga cerealella* Olivier., *C. cephalonica*, *O. surinamensis* and *T. granarium* (Veeranki and Reddy, 1999).

Borikar *et al.* (1977) conducted survey on insect pests of stored grain of different commodities in Marathawada region and eight different insect pests were recorded *viz.*, rice weevil, red flour beetle, flat grain borer, khapra beetle, pulse beetle, grain moth and rice moth.

Bharadwaj *et al.* (1979) recorded *S. oryzae*, *T. castaneum*, *S. cerealella*, *R. dominica*, *T. granarium* and *O. surinamensis* in maize samples collected from eight districts of Punjab.

Barak and Harein (1981) found that most common insects in farm stored shelled maize and wheat in South and Central Minnesota were *Ahashernus adnena* (Walt), *Plodia interpunctella* (Hubner), *T. castaneum* and *O. surinamensis*.

Pande and Das (1984) recorded insect pests of stored cereals viz., *S. oryzae*, *T. castaneum*, *Callosobruchus chinensis* L., *C. cephalonica* and *S. cerealella* were abundant.

The insect pests encountered in a survey at open markets of Nigeria were rice weevil and maize weevil which accounted for 72 percent of the total population. Red flour beetle and lesser grain borer accounted for 6 and 22% respectively (Ivbijaro, 1978).

Arbogast and Mullen (1988) reported the insect succession in stored corn ecosystem in south east Georgia. The species composition of the insect community changed as the maize deteriorated. *S. cerealella* was the most dominant species when the first sample was taken succeeded by *O. surinamensis* which declined rapidly, maize weevil *S. zeamais* was dominant during second and third year. *T. castaneum* was a significant component of the insect community throughout the storage period of eight years.

The most abundant species in a survey on stored barley and maize in the islands of Iefkas and Greece were *S. oryzae* and *S. granarium* L. (Buchelos and Katopodis, 1995).

Mahati (2002) studied the relative abundance of stored grain pests of maize through survey and reported that rice moth was abundant in six months old stocks, while rice weevil was found to be more abundant in all the godowns. Relative abundance of pest species varied with duration of storage in godowns and source of primary infestation at the field.

In a survey carried out in several grains and grain products stores in Alexandria, 5 lepidopterous insects belonging to 2 families and 10 coleopterous species belonging to 7 families were recorded. The rate of infestation was higher in spring and summer than in autumn and winter (El-Kashlan *et al.*, 1995).

Jalali and Singh (1992) based on grain utilization and adult emergence reported that the optimum number of eggs was 1500/kg grain. During the winter months ($24 \pm 1^{\circ}\text{C}$), peak emergence occurred after 100-130 days, whereas during the summer ($29 \pm 1.5^{\circ}\text{C}$), peak emergence occurred after 61-90 days.

Rostom (1993) recorded insects and mite infesting wheat, maize, wheat bran and dust samples, stored in or collected from Riyadh and Dammam provinces, Saudi Arabia, during two seasons. The relative abundance of the different species was discussed, and found to be dependent on factors of season, province and type of commodity. Common species found in both seasons and provinces, included 9 grainivorous and 2 non-grainivorous species.

Over a 9-month period, samples of maize and sorghum seeds were purchased monthly from markets located in three contiguous climatic zones of Nigeria. The grain samples were examined and insect pests found on them were recorded. Species of *Sitophilus*, *Rhizopertha* and *Sitotroga* were recorded. The relative incidence of the insect pests in the three zones is related to moisture availability reflected in grain moisture content (Ayertey and Ibitoye, 1987).

2.2 Biology of *Corcyra cephalonica*

2.2.1 Synonymy

C. cephalonica Stainton (Lepidoptera: Pyralidae) is a well known pest of stored products. Earliest reference to this insect was by Stainton (1866) who provisionally

named it as *Melissoblaptis cephalonica*, giving a brief description of the adult moth from specimen reared from dried currants.

Later, a new genus, *Corcyra*, was erected by Ragonot (1885) to accommodate this insect, the name being derived from the ancient name of *Corfu*, hence it was presumed to have been imported into England. Meyrick (1895) wrote a brief technical description of the only recognized species, *C. cephalonica* the other form, *transliniella*. Chittenden (1919) considered species *cephalonica* and *transliniella* were synonymous.

2.2. 2 Nativity and geographical distribution

According to Beveridge (1913) *Corcyra* is apparently of eastern origin and has been introduced into Europe and elsewhere by the rice trade. Although the pest is known to occur in many parts of Europe, Asia, Africa and America, *Corcyra* was not truly cosmopolitan Chittenden (1919). But, Richards and Herford (1930) considered it as cosmopolitan in distribution. Pest status in eastern countries was gauged by the results of a survey made by Freeman (1948). Then it was clear that *Corcyra* infestation in goods imported into the United Kingdom during 1944 - 46 and which came entirely from India, East and West Africa.

The rice moth *C. cephalonica* is cosmopolitan pest which is distributed both in tropical and subtropical countries, including India (Ramakrishna Ayyar, 1919); Sudan (Darling, 1952); Nigeria (Prevelt, 1963); United Kingdom (Freeman, 1976); Netherlands (Russell *et al.*, 1980); Philippines (Medina and Cadapan, 1982). Distribution map (map no. 656) constructed by CAB international for *C. cephalonica* gives detailed account on cosmopolitan distribution of the pest across the various geographical areas of the world (Anon, 2004).

2.2. 3 Range of food material liable to attack

Chittenden (1919) has christened the “rice moth” food range was extraordinarily wide and being noted in rice of various kinds, dried currants and other dried fruits. The

host range includes all forms of cocoa and chocolates, army biscuits, sesame seeds, cotton seeds, maize and bulrush millet, all in storage.

Munro and Thompson (1929) stated that *Corcyra* is one of the three important pests of stored cocoa, while Noyes (1930) reported it as a rare pest on cocoa and confectionary and according to him its normal food material was rice. Richards and Herford (1930) and Herford (1933) recorded *Corcyra* on currants, nutmeg, cocoa, groundnut, bulrush millet, cotton and linseed. In India, Ayyar (1934) reported it on rice and rice bran, cotton seed, groundnut, cholam, bengal gram, groundnut cake, wheat and wheat bran, red gram, green gram, tenai, ragi, cowpea and gingely seeds.

Krishnamurthy and Rao (1945) worked out the effect of adding yeast to rice bran and wheat bran and found it to improve nutritional quality of the mixtures.

Ramaswami *et al.* (1942), Swamy and Srinivasaya (1942) and Uberoi (1960) reported *Corcyra* infestation on various stored foods including spices. SeshagiriRao (1954) determined experimentally the acceptability of various edible stuffs to *Corcyra* to find out whether its range of feeding capacity goes beyond what had been worked out by previous workers. Of about thirty products of various categories tested, he found *C. cephalonica* to thrive best on cereal diet. Sorghum was more damaged and ragi the least damaged. Wheat bran and rice bran were naturally poor food and less damaged by the pest.

2.2.4 Pest status

Howe (1965) reported that *C. cephalonica* could multiply ten fold per month under favourable conditions, compared with fifty fold for *Ephestia cautella* (Walker) and *S. cerealella* (Oliver). Sinha (1975) gave climatic plasticity index (which combines temperature and humidity limits with intrinsic rate of natural increase) of 110 in *C. cephalonica* compared to 600, 575 and 330 for *E. kuehniella* (Zeller), *E. cautella* (Walker) and *Plodia interpunctella* (Hubner), respectively. Cox *et al.* (1981) found that

productivity of *C. cephalonica* declined after a few generations of standard laboratory rearing. Hodges (1979) suggested figure of $r = 10$ for the finite rate of increase per lunar month. However, the estimate of $r = 18$ by Shazali and Smith (1986) confirmed that the pest potential of *C. cephalonica* has been underestimated in the past.

2.2.5 Seasonal incidence

The pest occurs throughout the year but the peak activity of adults was exhibited from June to August that continued up to November and minimum during February to the end of May on rice (Ayyar, 1934). Observations made by SeshagiriRao (1956) indicated that pest incidence was less during the periods of high temperature and low relative humidity and high during low temperature, high humidity as in monsoon and winter months.

According to Atwal (1976) and Srivastava (1996) peak pest activity was observed from March to November, while it was September to October in Nigeria as reported by Mbata (1991). Jalali and Singh (1992) reported that the higher pest infestation occurred in summer months than in the winter months.

Study conducted by Bandyopadhyay and Ghosh (1999) in West Bengal on stored maize due to *C. cephalonica* was highest during July at Puralia region where hot and dry conditions existed; while in August at Kalyani region and Cooch Behar region where moderate temperature and humidity was prevailed.

A survey conducted by Ramesh and Vaidya (2001) in Himachal Pradesh on percentage of infestation by rice meal moth occurrence indicated the highest in rainy season (77.50%) followed by summer (62.5%) and least during winter months (24.16%). Kumar *et al.* (2002) reported the peak pest activity during February to October, where all the stages were noticed in Punjab.

2.2.6 Life history

2.2.6.1 Egg

The incubation period of *C. cephalonica* as reported by various workers, ranged from 4 to 6 days (Ayyar, 1934; Pruthi and Singh, 1950; Carmona, 1958; Thomas, 1961; Atwal, 1976; Cox *et al.*, 1981; Osman, 1984; Shazali and Smith, 1986; Ray *et al.*, 1990; Srivastava, 1996).

A shortest duration of 3.2 days on maize was recorded at 32⁰ C in Egypt by Kamel and Hassanein (1967), while longest duration of 9 days at 20⁰ C on maize was reported by Carmona (1958). The incubation period decreased with increasing temperature and humidity. Complete egg mortality occurred at temperature above 45⁰ C as reported by Hugar and JaiRao (1991).

The egg period recorded by Manjunath (1993) ranged from 4 to 8 days at 26⁰ C and 60 per cent relative humidity. Kumar *et al.* (2002) recorded the average incubation period of 3.1 days on sorghum and 3.89 days at 30⁰C on wheat. Prakash and Kumar (2005) recorded shortest incubation period of 4.21 days on bajra, 5.32 days on rice and longest of 7.41 days on sorghum at 28⁰ C and 75 per cent humidity.

Patel and Patel (2007) studied the biology of *C. cephalonica* on broken grains of sorghum, wheat, pearl millet and rice at room temperature in the laboratory, the mean egg period ranged from 4.06 to 5.06 days.

2.2.6.2 Larva

2.2.6.3 Number of larval instars

Rohwer and Middleton (1922), Miles (1931) and Richards and Thomson (1932) have found that the number of instars varied with sex, the female usually having more moults than the male.

Parker (1930) stated that increased temperature caused increase or decrease in the number of moults while insufficient food usually lengthened the life cycle there by increasing the number of instars (Back and Cotton, 1926; Gaines and Campbell, 1935; Potter, 1935; Stone, 1941; Basden, 1950). Primarily, the variation in the number of larval instars in *Corcyra* linked with sex, as in case of *E. cautella* (Richards and Thompson, 1932). Satterthwait (1933) and Good (1933) described the difference in number of instars due to individual difference in the larva, while Waloff (1948) stated that number of instars attributed to inherited characters.

Ayyar (1934) described the complete morphology of different larval instars of *C. cephalonica*.

SeshagiriRao (1954) reported that the number of larval instars was not constant, 8 in some cases and 6 or 7 in others. He stated further that the males had 6 or 7 instars while females had 8 instars. However, he has opined that the difference in the number of larval instars had reference to sex. A detailed key to the larval duration and measurements with respect to sex was given by Usman (1968).

2.2.6.4 Larval duration

Ayyar (1934) reported that the duration of 6 larval instars ranged from 5 to 6, 7 to 8, 6 to 7, 7 to 10, 4 to 5, 4 to 5, and 4 to 5 days with an average of 6, 7, 7, 6, 8, 4, 4 and 4 days, with total larval duration of 46 to 56 days, respectively on rice. SeshagiriRao (1954) reported that larval instar durations ranged from 4 to 5, 4 to 5, 4 to 5, 4 to 5, 4 to 8, 4 to 6, 5 to 6 and 7 to 9 days with a mean of 4, 4.7, 4.7, 4.7, 6.9, 4.9, 5.3 and 7.8 days respectively, on maize, which resulted in total larval duration of 48 to 60 days at 90⁰ F and 64.7 per cent humidity.

Usman (1968) recorded 2 to 3.5, 2 to 3, 2 to 3.5, 2.5 to 3.5, 2 to 3.5 and 3 to 3.95 with a mean of 2.45, 2.93, 2.48, 2.97, 3.18 and 3.99 days for six larval instars in males on

broken jowar grains at 30⁰ C and 80 per cent relative humidity and he stated that the first larval instar was shortest and last was longest and durations of instars depended on food availability.

Kamel and Hassanein (1969a) in Egypt reported average larval duration of 46.5 days in powdered field beans followed by 58.5 days and 77 days, respectively on wheat flour and wheat bran. Shazali and Smith (1986) recorded average larval period of 21.7 to 29.8 days at 25 to 35⁰ C and 60 to 80 per cent relative humidity on sorghum flour. Mbata (1989) recorded average larval periods of 29.2, 26.7, 48.1 and 47.2 days on broken maize, maize, whole and broken cocoa beans, respectively.

Manjunath (1993) recorded average larval instar durations of 4.42, 5.04, 3.46, 3.42, 5.21, and 8.42 days and 4.19, 4.92, 3.43, 3.27, 5.12, 9.13 days for 6 larval instars in males and females, respectively, with total larval period of 29.97 and 30.92 days on maize at 28⁰ C and 70 per cent relative humidity. Kumar and Kumar (2002) recorded average larval period of 23.78 days on maize and 35.45 days on rice.

Patel and Patel (2007) reported that the duration of 1st, 2nd, 3rd, 4th, 5th, 6th and 7th instars varied from 4.03 to 6.77, 4.10 to 7.20, 4.83 to 7.16, 5.85 to 7.41, 6.44 to 7.52, 5.75 to 7.81 and 5.76 to 8.09 days, respectively.

2.2.6.5 Pupa

The pupa of *C. cephalonica* needed 10 to 14 days, averaging 12 days on rice in south India (Ayyar, 1934; Pruthi and Singh, 1950; Thomas, 1961) while it was 4.5 to 10 days on rice with an average of 10.2 days at 25 to 35⁰ C and 60 per cent relative humidity as recorded by Shazali and Smith (1986).

Hugar and JaiRao (1991) studied the effect of temperature and humidity on the pupal development of the pyralid *C. cephalonica* on stored sorghum in the laboratory at 15-40⁰ C and 30-90% RH. The pupal period decreased with increase in temperature,

being longest at 15⁰ C and shortest at 35⁰ C. Pupal period also decreased with increased humidity.

Mbata (1989) recorded average pupal period of 7.5, 8.3, 7.6, 8.4 and 8.5 days at 30⁰ C and 80 per cent relative humidity on groundnut, cocoa, maize, rice and cowpea respectively, in Nigeria while it was 7.7 and 8.23 days on maize and rice as recorded by Kumar *et al.* (2002).

Prakash and Kumar (2005) studied that pupal period was rapid in *P. americanum* (10.11 days) and slowest in *Sorghum bicolor*.

Patel and Patel (2007) studied the biology of *C. cephalonica* on broken grains of sorghum, wheat, pearl millet and rice at room temperature in the laboratory and pupal period was found to be 1.23 to 1.74 and 8.40 to 10.58 days, respectively.

2.2.6.6 Total developmental period

Ayyar (1934) recorded total developmental period of 38 days on ragi and maize, 42 days on wheat, 53 days on rice, 57 days on sorghum and 66 days on cowpea. Seshagiri Rao (1954) recorded 47 to 57 days with an average 48.6 days on broken maize. Teotia and Singh (1975) recorded 44.97 days on maize at 26.5⁰ C and 73 per cent relative humidity. Chatterji (1961) stated that the total developmental period reduced as the moisture content increased from 9 to 12 per cent and recorded minimum developmental period of 44.6 days at 12 per cent and 48 days at 9 per cent moisture content on broken rice at 92⁰ ± 5⁰ F and 40 per cent relative humidity.

Cox *et al.* (1981) recorded total developmental period of 42 days at 25⁰ C and 70 per cent relative humidity on wheat in United Kingdom. Medina and Cadappan, (1982) recorded 32 days on rice bran and 42.7 days on maize, while it was 38.84 days at 30⁰ C. Parameshwar and JaiRao (1987a) recorded total larval period of 52.22 days at 25⁰ C and 75 per cent relative humidity on maize.

Etman *et al.* (1988) recorded total developmental period of 40.9 days for males and 43.5 days for females at 28⁰ C and 65 per cent relative humidity, while it was 50.03 days on maize as recorded by Ray (1994).

Allotey and Azalekor (2000) recorded total developmental period of 33.2 to 45.3 days on broken and powdered form of groundnut at 27.5 to 30⁰ C and 60 to 73 per cent relative humidity. Bartels (2002) recorded total developmental period of 35.5 to 48.2 days on cocoa, while it was 65.08 to 69.24 days on groundnut as recorded by Haritha *et al.* (2000). Prakash and Kumar (2005) recorded 44.05 days, 48.15 days and 39.99 days, respectively, on rice, sorghum and cumbu.

2.2.6.7 Adults

Stainton (1866) first recorded the adult specimens from dried currants. Meyrick (1928) described the adult *Corcyra* moths as “face with projecting tufts, tongue rudimentary, labial palpi short and head ochreous whitish. Forewings grayish ochreous, along dorsum paler or whitish sprinkled; veins more or less streaked suffused with dark fuscous, disc anteriorly sometimes wholly suffused dark fuscous”.

2.2.6.7.1 Sex differentiation in adults

Ayyar (1934) was the first person to specify sexual dimorphism in the moths, indicating the sexes were dissimilar in size, where females were larger than males and the head was elongate and labial palpi was projected like snout, but head was less conspicuous and labial palpi was blunt in males.

2.2.6.8 Adult longevity

Ayyar (1934) reported that male longevity ranged from 9.5 to 10.5 days and female longevity 8.5 days on rice. SeshagiriRao (1954) from his observations reported

that the maximum life of a female was 22 days and of male was 13 days; the average was 7.2 days and 4.9 days, respectively. Unmated females live longer and hold back most of their eggs.

Carmona (1958) recorded difference in adult lifespan of about 8 days between unmated males and females at 27⁰ C and 71 per cent relative humidity and 7 days at 27.5⁰C and 70 per cent relative humidity in United Kingdom. Kulkarni (1969) recorded average female longevity of 6.9 days on sorghum. Etman *et al.* (1988) found that the mated males and females live for 9.1 and 8.3 days with the virgins live 7 and 8 days in both males and females, respectively.

Manjunath (1993) recorded highest longevity of adults which ranged from 4 to 19 days with a mean of 8.2 days without food, whereas adults provided with 50 per cent of honey solution lived 8 to 14 days with a mean of 9.6 days and he stated that the unmated moths lived longer time compared to mated moths.

SuChiung and WuKang (1998) recorded mean longevity of mated males and females as 8.1 and 12.9 days of those unmated was 10.2 and 16.4 days, respectively in Taiwan at 30⁰ C and 75 per cent relative humidity on brown rice. Average adult longevity of 9.8 and 7.55 days in males and females on sorghum was recorded by Kumar *et al.* (2002).

Patel and Patel (2007) studied the biology of *C. cephalonica* on broken grains of sorghum, wheat, pearl millet and rice at room temperature in the laboratory and reported that the longevity of male moth was longer (9.53 days) in rice, while it was shorter (8.18 days) in wheat. The female lived longer (8.93 days) on sorghum, while it lived shorter (7.43 days) in pearl millet.

2.2.6.9 Mating

Ayyar(1934) recorded mean number of mating per male was 3.2, while that of females 1.2 and multiple mating occurred in 16 per cent of the moths stated that before

mating. He stated that mating occurs after few minutes to hours of adult emergence and in rare cases it occurred immediately after moth emergence and maximum mating response was recorded in second night after emergence. According to Thomas (1961) the adults copulate within a day or two after emergence and started laying eggs.

2.2.6.10 Fecundity

Ayyar (1934) observed that number of eggs laid per day varied considerably under Indian conditions and normally laid at night, but occasionally during day time. The oviposition was normally stimulated by rough surfaces, eggs were laid singly or occasionally in groups of 3 to 4 and he recorded 89 to 191 eggs with an average being 190.5 eggs/ female moth.

Pruthi and Singh (1950) stated that eggs were laid indiscriminately and a single female may lay about 90 to 200 eggs, while SeshagiriRao (1954) recorded maximum fecundity of 345 eggs per female with an average of about 115.7 eggs per female on maize. Seshagiri Rao (1956) recorded average fecundity of 139 and 93 eggs per female in bigger and smaller moths respectively. He stated that presence of food was not essential to induce oviposition and eggs were laid till death of the moth.

The average fecundity as recorded by various workers was 62 to 150 eggs per female in a period of 2 to 14 days on rice (Atwal, 1976 and Srivastava, 1996). Devraj Urs and Mukherjee (1966) observed that the fecundity increased on groundnut. Russel *et al.* (1980) recorded 18 to 467 eggs per female deposited at 28⁰ C and 70 per cent humidity on sorghum, while it was 131.8 eggs per female within duration of 5.1 days at 30⁰ C and 70 per cent relative humidity by Mbata, (1989). Ray *et al.* (1990) recorded net reproductive rate of *C. cephalonica* as 149.81 eggs per female at 28⁰ C and 75 per cent relative humidity on crushed jowar grains.

Manjunath (1993) reported fecundity of *C. cephalonica* which ranged from 358 to 620 eggs per female with an average of 464.67 eggs were provided with 50 per cent

honey solution, where it was 306 to 619 with an average of 468 eggs per female in the absence of adult food. He stated that virgin females laid more number of eggs than mated females. Bartels (2002) stated that oviposition was stimulated by crevices and chemical stimuli and moths avoided laying on smooth surfaces. He recorded an average fecundity of about 231.3 eggs per female on cocoa.

Jacob *et al.* (2002) recorded average fecundity of 287.26 eggs per female on bajra. Prakash and Kumar (2005) recorded an average fecundity of 68.11, 62.12 and 72.10 eggs on rice, sorghum and pearl millet, respectively.

Patel and Patel (2007) reported that the highest fecundity (159 eggs) in females reared on sorghum than the females of rest of the commodities (broken grains of sorghum, wheat, pearl millet and rice).

2.2.6.11 Oviposition

Ayyar (1934) reported that the oviposition was stimulated by rough surfaces and eggs were securely fastened to the surface by some sticky material. SeshagiriRao (1954) stated that presence of larval food material within sight or reach of the moths was not essential to induce oviposition. According to Carmona (1958) moths commenced the oviposition within 18 hours of mating and completed in 4 days. Pajni and Gill (1974) stated that the number of eggs laid in presence of light was less compared to under darkness condition.

According to Teotia and Singh (1975), broken grains were an important prerequisite to induce oviposition and number of eggs. Raj (1976) stated that over crowding of adults invariably reduced oviposition rate and increased egg mortality. The oviposition commenced within 18 hours after mating and completed in 4 to 7 days (Mbata, 1989 and Carmona, 1958).

Manjunath (1993) recorded 1.69, 8.9 and 0.33 days for preoviposition, oviposition and post-oviposition periods. Haritha *et al.* (2000) recorded 6 days and 0.525 days of oviposition period and pre-ovipositional period, respectively on sorghum.

Patel and Patel (2007) reported that the preoviposition, oviposition and postoviposition period ranged from 1.18 to 1.45, 5.50 to 6.21 and 0.88 to 1.23 days on different host commodities.

2.2.6.12 Damage by rice moth

The pest has a wide range of distribution in rice growing areas of the world including India, Pakistan, Burma and Sri Lanka. It is a serious pest of stored rice and jowar and thrives well in humid climate. Now it has been recorded on all most all food stuffs. Besides feeding on grains and polluting food grains with copious quantities of frass and silken tubes webbing together the food grains into large clumps. The presence of fleshy larvae leads to serious public discrimination.

Seshagiri Rao (1956) reported groundnut kernels infested by *C. cephalonica*, resulted in decreased thiamine content, reduction in the viability of seeds, reduction in the oil and increase of fat percentage. It was further reported that the damage caused by *C. cephalonica* to decorticated nuts is responsible for the development of mouldness and caking of nuts.

Avilespacheco and Acevedo (1983) reported the nature and extent of damage caused by larvae of *C. cephalonica* to polished rice. Feeding by the larvae on surface of the grains caused to stick together and forms clumps, which contained intact and broken grains, exuviae, silken threads, dust and detritus. Each larva gave rise to 4 to 6 clumps and single larva completes its development by feeding 0.567 g and by contaminating 75 g of grain by forming clumps. When more than 16 larvae were developing in 250 g, a change in the colour of rice was noticed, together with an unpleasant odour.

2.2.6.13 Food consumption by *C. cephalonica*

SeshagiriRao (1954) recorded average weight of maize consumed by *Corcyra* larva throughout entire period of development ranged from 0.12 to 0.33g. Parmeshwar and Jairao (1987a) conducted a study to estimate the food consumption by individual larva and known number of larvae of *C. cephalonica* and found that 0.59g of broken sorghum required for an individual larva to complete its lifecycle further reported that food consumption increased 5 to 10 times during the act of development which ranged from 4.360g to 6.116g for 10 larvae. The remaining amount of food was thus lost by mixing with frass, faeces etc.

Manjunath (1993) recorded average food consumed by each larva of *C. cephalonica* was 0.37g, 0.24g, 0.15g, 0.15g and 0.18g in sorghum, bajra, rice, wheat and maize, respectively. It also contaminate the food by mixing with frass, faeces and excreta, body parts etc.

2.2.6.14 Extent of damage

Ayyar (1934) reported that under favourable condition no material in storage was free from *C. cephalonica* infestation; damage done was directly proportional to the number of insects present. Mbata (1991) recorded 4.9 to 5.7 per cent loss on groundnut due to stored pest *C. cephalonica* with peak infestation noticed in September to October in Nigeria.

A survey conducted by Singh and Yadav (1995) in stored wheat revealed 9.19 per cent infestation and 2.03 per cent weight loss in stored maize Haryana while it was 8 per cent infestation on maize in Andhra Pradesh as reported by Veeranki and Reddy (1999).

A survey conducted by Bandyopadhyay and Ghosh (1999) in West Bengal on infestation level of three stored pests, *R. dominica* and *T. castaneum* and *C.cephalonica* varied from 4.3 to 25.5 per cent while it was 3.0 to 23.4 per cent damage, respectively on

wheat and rice. Ramesh *et al.* (2000) reported that the combined percentage of damaged grains due to infestation of *S. oryzae* (66.14%), *T. castaneum* (23.53%), *O. surinamensis* (4.59%), *C. cephalonica* (3.80%) and *R. dominica* (0.79%) with an average grain damage of 18.09% and 3.96% weight loss in rice in Kangra district of Himachal Pradesh.

2.3 Shelf life

Grain infestation in different storage structures in descending order was room (14.8%), thekka (13.7%), parchhatti (12.8%), bukhari (11.7%), kothi (9.9%), jute bag (9.8%) and metal bin (3.2%). Thus none of the structure was free from infestation. Metal bin was found most effective and only 3.2 per cent infestation was observed (Singh and Yadav 1995).

Srivastava(1996), ShankarDass (1977) also found metal bin better than other structures. Dhaliwal *et al.* (1977) observed low moisture content in metal bin.

Sonelal and Srivastava (1985) recorded banda storage provided the maximum protection to stored wheat against the insects. Bindi and mud bin were less desirable for storing wheat as these structures could not provide adequate protection. Bag storage was the worst affected storage system.

Borikar *et al.* (1977) observed that grains stored in kangi were heavily infested with rice weevil, lesser grain borer, pulse beetle and red flour beetle than bagged commodities. However, the infestation of grain moth, flat grain beetle and rice moth was more in bagged produce.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation was conducted during 2009-2010 at entomology laboratory of the Project Co- ordination Centre of the All India Co-ordinated Small Millet Improvement Project, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru. The material used and the methods followed are described here in.

3.1 To record the incidence of insect pests occurring on stored value added products

The study was initiated during March 2009 and continued till February 2010. For this purpose a known weight of sample about 200 gms of Ragi value added products *viz.*, Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku) (Plate 1-a, b, c, d and e) was taken in a plastic container and placed at five different locations *viz.*, ZARS Storeroom, V. C. Farm Storeroom, Mandya City, Hebbal Girl's Hostel and PG Girl's Hostel and replicated four times. Samples were examined at weekly interval; further, recorded and counted the insect pests that have occurred on Ragi value added products mentioned above. Further, the same insect pests were brought to the laboratory in a plastic vials and identified by the taxonomists of the Dept. of Entomology, GKVK, Bengaluru-560 065, for further study.

Absolute counts of insect pests occurred on different ragi value added products were counted in all the locations at weekly interval. Later the mean number of insects per sample was worked out and the same is presented, in the study.

3.2 To study the biology of *C. cephalonica*

3.2.1 Maintenance and build up of stock culture

Stock culture of *C. cephalonica* was collected from National Bureau of Agriculturally Important Insects Hebbal, Bengaluru. As per recommendation 0.5cc of egg were used to infest 1kg of broken foxtail millet. The culture was maintained on foxtail



Plate 1a. Hurihittu



Plate 1b. Papad



Plate 1c. Vermicelli



Plate 1d. Sandige



Plate 1e. Chakali

Plate 1. Ragi value added products

millet with 12% moisture content, kept in plastic jars with 3kg capacity. Then the jars were filled with 2kg of broken foxtail millet and infested with 1cc of *C. cephalonica* eggs and covered with muslin cloth (Plate 2-a and b). One third space left in jar to reduce the crowding. The dead larvae were removed periodically, leaving behind only live larvae in the culture to avoid bacterial contamination. To prevent contamination of predatory mites that inhibit the build up of *C. cephalonica* culture, the flour or powder clumps formed due to feeding was removed with the help of forceps. The adults emerged were collected in glass specimen tubes (6 X 2cm) and were transferred to egg laying cage.

3.2.2 Egg stage

The method followed for collecting *C. cephalonica* eggs was a modification of that used by Teotia and Singh (1975). An egg laying apparatus consisted of a hollow glass cylinder (18cm long X 13cm diameter), two ends of which provided with lids fitted with wire gauge (60 to 70mm mesh) and it was designed to obtain the eggs of this insect. The glass cylinder was kept on a cone held in place over an iron sheet cylinder used as stand. The upper lid was covered with a thick black cloth within 12 hrs, the females kept in the glass cylinder laid eggs which were collected in the cone beneath.

In the present study a slight modification was adopted. An egg laying apparatus consists of a glass funnel (15cm X 10cm) and its lower end is fitted with wire mesh (60-70 mesh) to obtain eggs of this insect. The upper lid was closed with thick white muslin cloth to provide rough surface for egg laying and lid was tightly fitted. This apparatus was kept on a conical flask which was used as a stand. Then freshly emerged adults were sexed and released into the funnel. The eggs laid on muslin cloth fell on wire mesh and was collected in conical flask. The experimental set was maintained at 25 to 30⁰ C with 60 to 70 per cent relative humidity. The eggs collected in the flask and on the surface of the cloth were removed daily and these eggs were used to study the biology and other studies.

3.2.3 Life history studies on *C. cephalonica*

Life history study was conducted under laboratory conditions on ragi value added products. Five grams of broken ragi value added products were placed in hundred cleaned plastic containers (4 X 2cm) (Plate 2c). Later freshly hatched first instar larva one per each was introduced by using camel hair brush, from petridish in which eggs were kept for hatching. Observations on duration of different larval instars as well as pupal period were made in respect of all the enclosed larvae. Observation was recorded from a day after introduction of larva into tubes.

The larvae start forming cluster around them and it start feeding inside the cluster. Therefore, everyday three clusters was dissected and observed carefully to note the stages of the larva until completion of the developmental period, commencing from the day of release. Presence of moulted skin and head capsule inside the clump was an indication for determining the larval instars. Measurements of length and breadth of egg, larval head capsule width, thorax and body length was also recorded, using calibrated ocular micrometer mounted on stereo binocular microscope. Cluster was dissected until pupal stage was noticed. The emergence of the adult was observed from the same stock and pupal period too was also being determined.

3.2.3.1 Ovipositional studies

Newly emerged moths were obtained from the mass culture was sexed based on the difference in labial palpi which is elongated and snout like projection, in females and blunted in case of males (Ayyar, 1934). A pair of moths was released in a tube, open end enclosed with cotton plug. Observations on mating period, preovipositional period, ovipositional period and post ovipositional period were recorded. Number of eggs laid per female was recorded till egg laying ceased or till the death of the female moth. In all, fifteen pair was enclosed separately in fifteen tubes.



Plate 2a. Wide mouth plastic containers



Plate 2b. Oviposition cage for *C. cephalonica*



Plate 2c. Plastic containers

Plate 2. *Corcyra cephalonica* rearing appliances

3.2.3.2 Adult longevity

The ability of the adults of *C. cephalonica* to live in the presence or absence of food was determined by enclosing male and female moths obtained from culture separately. Fifteen glass vials was maintained for both mated and unmated males and females to test longevity. Fifteen such tubes were maintained for each of the females without food to record longevity and fecundity of females. Similarly, another set of fifteen vials enclosed with freshly emerged females, each was set up with 50 per cent honey solution as a food. Adult longevity and number of eggs laid per female was recorded for those female moths provided with food. Temperature and relative humidity prevailing in the laboratory was recorded.

3.2.4 Nature of damage and infestation behavior

3.2.4.1 Feeding behavior

Larva of *C. cephalonica* usually bore into the products by forming silken web and completes immature development (Ayyar, 1934). Constant observations was recorded on nature of feeding, growth and development of *C. cephalonica* on ragi value added products and cluster formation.

3.2.4.2 Amount of food requirement by individual larva

Two sets of twenty-five specimen (6 X 2cm) each with three grams of ragi value added products were filled. Observations on amount of food required for individual larva was recorded. The excreta and silken cocoon formed was removed after pupal formation with the help of forceps and then left out food was recorded as final weight. Amount of food required for individual larva was recorded by subtracting final weight from initial weight.

3.2.5 Influence of Ragi value added products viz., Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku) on the biology of *C.cephalonica*

The biology of *C. cephalonica* was conducted on all hosts to know the preference of the pest. A Known weight (5g) of all ragi value products was placed in a small plastic vials measuring 4X2cm. Individual freshly hatched larva was released in all the vials. The same was replicated five times. Later detailed observations was recorded on larval and pupal duration, adult longevity, fecundity, feeding behaviour, and total developmental period. Further, incubation period was also recorded.

3.3 Shelf life of different value added products of ragi

Two hundred grams of ragi value added products viz., Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku) was taken in a different containers such as cloth bag (T₁), polythene cover (T₂), glass container (T₃), mud container (T₄), and steel container (T₅) (Plate 3-a, b, c, d and e). The same was replicated four times. These samples were observed at an interval of 30 days to 180 days to assess the pest infestation. The data thus collected in the study was analyzed statistically using CRD two factorial design.



Plate 3. Different storage structures

- a. Cloth bag**
- b. Polythene container**
- c. Glass container**

- d. Mud container**
- e. Steel container**

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results pertaining to the insect pests of ragi value added products namely Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku), biology of *C. cephalonica* on ragi value added products, nature of damage and infestation behaviour and shelf life of ragi value added products are presented in the following paragraphs.

During the period of study the following insect pests at different locations were recorded on ragi value added products (Table 1).

4.1. Insect pests on ragi value added products

***Sitophilus oryzae* Linn. (Curculionidae : Coleoptera)**

The rice weevil, *Sitophilus oryzae* was found infesting on fried ragi flour in varying intensities throughout the year. The adult weevil was slightly pinkish to brown in colour with four yellow coloured spots on the elytra (Plate 4a). Both adults and grubs web the product and fed within the product. The incidence of weevil varied from 3.75 to 65.5 at all study locations on Hurihittu. The incidence was higher during November (65.5 insects/sample) and relatively less in April (3.75 insects/sample).

Almost the same trend was observed on other value products of ragi viz., Vermicelli, Papad and Sandige. Over all, the pest incidence was lower during February to May and maximum during June to January at all locations (Table 2, 3, 4 and 5). There was no incidence of weevil on Chakali (Muruku) throughout the year.

***Corcyra cephalonica* St. (Pyralidae : Lepidoptera)**

The rice moth, *Corcyra cephalonica* St. (Plate 4b) cause considerable damage to all the products. The adults were comparatively small moths, exhibiting considerable variation in size. They were uniformly dark grey in colour with a few dark hair lines.

Table1. Insect pests recorded on Ragi value added products during 2009-2010

Sl. No	Products	Insects	Family	Order	Location
1	Hurihittu	<i>S. oryzae</i> (Linn.) <i>C. cephalonica</i> (St.) <i>C. maculatus</i> (Linn.) <i>T. castaneum</i> (Herbst) <i>L. serricorne</i> (Fb.)	Curculionidae Pyralidae Bruchidae Tenebrionidae Anobiidae	Coleoptera Lepidoptera Coleoptera Coleoptera Coleoptera	All
2	Vermicelli	<i>S. oryzae</i> (Linn.) <i>C. cephalonica</i> (St.) <i>C. maculatus</i> (Linn.) <i>T. castaneum</i> (Herbst) <i>L. serricorne</i> (Fb.)	Curculionidae Pyralidae Bruchidae Tenebrionidae Anobiidae	Coleoptera Lepidoptera Coleoptera Coleoptera Coleoptera	All
3	Papad	<i>S. oryzae</i> (Linn.) <i>C. cephalonica</i> (St.) <i>T. castaneum</i> (Herbst)	Curculionidae Pyralidae Tenebrionidae	Coleoptera Lepidoptera Coleoptera	All
4	Sandige	<i>S. oryzae</i> (Linn.) <i>C. cephalonica</i> (St.)	Curculionidae Pyralidae	Coleoptera Lepidoptera	All
5	Chakkuli	Nil	Nil	Nil	Nil

Table 2. Seasonal incidence of *S. oryzae* on Hurihittu, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya City	Hebbal girl's Hostel	P.G girl's hostel	
March- 2009	6.50	5.50	5.00	4.25	4.00	5.05
April	8.75	7.18	6.60	6.43	3.75	6.54
May	10.87	10.68	7.23	6.72	4.62	8.01
June	17.12	15.06	12.43	7.00	5.87	11.49
July	25.06	22.43	20.50	9.43	8.31	17.14
August	33.56	33.00	31.00	12.68	11.00	24.24
September	45.81	45.12	44.00	15.43	14.68	33.00
October	57.81	55.12	52.75	20.00	18.87	40.91
November	65.50	63.00	60.12	27.00	24.00	47.92
December	43.12	40.68	40.00	20.93	16.56	36.18
January- 2010	20.12	20.31	16.00	11.68	9.18	15.45
February	12.00	15.00	10.00	8.00	7.00	10.40

Table 3. Seasonal incidence of *S. oryzae* on vermicelli, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya City	Hebbal girl's Hostel	P.G girl's hostel	
March- 2009	5.00	4.75	4.50	4.00	3.50	4.35
April	8.56	8.00	5.00	4.50	3.62	5.93
May	11.23	8.56	5.25	4.37	3.81	6.64
June	15.43	13.62	8.25	5.50	5.25	9.61
July	21.23	20.50	12.68	8.56	7.00	14.03
August	31.25	30.93	19.00	11.43	10.5	20.62
September	45.25	43.37	28.50	14.56	13.5	28.03
October	54.31	52.62	41.50	18.06	18.06	36.98
November	61.12	61.00	50.43	25.12	23.50	44.23
December	44.06	43.50	34.37	20.43	16.62	31.79
January- 2010	18.62	16.50	13.68	10.87	8.56	13.64
February	12.87	12.06	9.00	7.87	6.43	9.64

Table 4. Seasonal incidence of *S. oryzae* on papad, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's Hostel	P.G girl's hostel	
March- 2009	4.00	3.25	3.00	2.50	2.00	2.95
April	7.50	7.00	4.25	3.00	2.75	4.90
May	10.00	7.50	4.87	3.37	2.80	5.70
June	13.68	10.31	6.56	4.87	4.37	7.95
July	19.87	18.00	8.75	7.43	6.68	12.14
August	29.75	28.12	11.31	10.43	9.68	17.85
September	44.00	40.75	15.93	13.43	12.00	25.22
October	52.81	49.87	21.62	18.31	16.50	31.82
November	59.93	58.62	24.50	21.75	21.25	37.21
December	40.75	39.93	20.68	19.25	14.75	27.07
January- 2010	18.37	14.25	10.50	9.93	7.56	12.12
February	11.31	10.62	6.37	6.00	5.31	7.92

Table 5. Seasonal incidence of *S. oryzae* on sandige, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's Hostel	P.G girl's hostel	
March- 2009	3.50	3.25	2.80	2.40	2.00	2.79
April	7.00	6.00	3.00	2.00	2.25	4.05
May	8.00	7.00	4.00	3.10	2.50	4.92
June	12.70	9.20	5.30	3.37	3.33	6.78
July	18.78	17.54	7.50	7.30	6.50	11.52
August	28.75	25.12	10.31	9.35	8.50	16.40
September	39.00	37.57	14.35	12.42	10.70	22.80
October	43.78	42.87	20.62	17.73	15.53	28.10
November	45.39	46.62	23.50	20.50	19.30	31.06
December	38.75	36.73	19.68	19.30	13.57	25.60
January- 2010	17.73	13.20	9.50	8.30	6.65	11.07
February	10.21	10.00	5.32	5.10	4.71	7.06

Newly emerged larva after hatching was very active and started crawling in search of food. After reaching the food, it started scraping or webbing the product. When it was a damaged one, it started feeding on the product. Subsequently, the faecal pellets were used by the larva to form a cluster of products and were found feeding inside the cluster. Later stage of infestation reveals dense white silken cocoon with damaged products, frass and excreta matted together. The larva is creamy white with yellowish head; which was the only damaging stage and fed voraciously.

The incidence of *C. cephalonica* varied from 4.81 – 71.37 insects/sample at all study locations on Hurihittu. The pest incidence was higher during June – January and relatively less from February – May (Table 6), at all locations on Hurihittu.

Almost the same trend was noticed on other three products namely Vermicelli, Papad and Sandige, at all locations (Table 7, 8 and 9). Further there was no incidence of *C. cephalonica* on Chakali (Muruku).

***Callosobruchus maculatus* Linn. (Bruchidae : Coleoptera)**

The pulse beetle, *Callosobruchus maculatus* is small dark brown and rounded abruptly (Plate 4c); grubs fed on fried ragi flour, after mixing the content together. The incidence of beetle was noticed only on fried ragi flour and vermicelli.

The incidence of pest varied from 1.50 to 45.37 insects/sample at all locations. The pest incidence was maximum from July to December and relatively less during January – June at all locations on Hurihittu (Table 10).

Almost the same trend was observed on vermicelli at all locations (Table 11). The incidence of pulse beetle was not noticed on Papad, Sandige and Chakali (Muruku) at all locations during the study period.

Table 6. Seasonal incidence of *C. cephalonica* on Hurihittu, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya City	Hebbal girl's Hostel	P.G girl's hostel	
March- 2009	7.00	6.50	6.30	5.50	5.00	6.06
April	12.62	8.87	7.50	6.53	5.37	8.17
May	15.00	14.00	8.50	8.31	7.30	10.62
June	22.37	20.12	12.50	9.25	8.40	14.52
July	27.18	25.50	19.37	12.68	12.12	19.37
August	40.87	37.37	31.18	17.18	15.81	28.48
September	53.50	50.87	43.50	23.37	20.87	38.42
October	63.93	56.37	47.81	27.37	24.31	43.95
November	71.37	64.31	60.21	36.12	22.68	50.93
December	47.25	46.81	41.18	29.87	13.81	35.78
January- 2010	25.75	24.12	16.87	17.56	8.56	18.57
February	19.12	19.10	10.00	11.93	4.81	12.99

Table 7. Seasonal incidence of *C. cephalonica* on Vermicelli, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store Room	V.C. Farm	Mandya City	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	6.00	5.50	6.20	5.50	5.00	5.64
April	8.00	7.50	6.00	5.43	3.93	6.17
May	11.75	8.87	6.25	6.00	4.62	7.49
June	19.50	17.75	11.06	8.25	7.00	12.71
July	24.87	22.62	19.43	12.12	11.06	18.02
August	36.50	36.37	29.62	16.18	15.12	26.75
September	51.00	48.37	40.06	21.68	20.06	36.23
October	61.06	53.25	49.93	26.25	23.18	42.73
November	69.87	61.43	57.25	34.93	24.18	49.53
December	45.25	47.93	40.43	30.12	13.81	35.50
January- 2010	23.25	22.56	14.75	16.62	12.00	17.83
February	17.37	16.43	13.00	10.81	7.43	13.00

Table 8. Seasonal incidence of *C. cephalonica* on Papad, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store Room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	6.50	4.50	4.30	3.50	2.50	4.26
April	10.18	8.06	8.00	4.31	2.62	6.63
May	11.06	10.5	8.50	4.18	3.68	7.58
June	17.87	15.87	10.31	7.37	6.12	11.50
July	22.37	20.93	12.75	10.93	10.93	15.58
August	35.25	35.12	18.8	15.62	15.18	23.99
September	49.5	47.12	25.25	20.93	19.56	32.47
October	59.62	51.75	31.43	25.62	22.06	38.09
November	68.18	60.75	38.87	33.56	25.50	45.37
December	45.93	42.75	33.18	26.31	20.06	33.64
January- 2010	20.73	19.87	17.43	16.12	10.75	16.98
February	14.00	13.00	12.87	10.25	6.25	11.27

Table 9. Seasonal incidence of *C. cephalonica* on Sandige, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	4.50	4.25	4.00	3.75	3.00	3.90
April	5.30	5.00	4.75	3.80	3.30	4.43
May	9.10	9.00	8.80	3.90	3.50	6.86
June	13.89	12.73	11.50	4.43	4.30	9.37
July	19.79	18.00	15.32	8.70	8.50	14.06
August	29.79	27.57	22.45	10.50	9.30	19.92
September	41.00	39.23	28.70	13.53	12.50	26.99
October	44.70	43.80	41.50	19.43	17.23	33.33
November	46.93	45.39	43.20	22.32	21.23	35.81
December	39.25	38.50	37.00	20.53	19.35	30.92
January- 2010	18.37	14.20	10.75	9.45	8.54	12.26
February	11.31	10.21	6.38	6.30	4.60	7.76

Table 10. Seasonal incidence of *C. maculatus* on Hurihittu 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Form	Mandya City	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	2.50	2.00	1.75	1.60	1.50	1.87
April	4.50	4.00	3.50	3.00	2.50	3.50
May	7.50	6.37	4.00	3.25	2.93	4.81
June	10.62	10.31	5.06	4.31	2.37	6.53
July	15.81	14.18	10.5	5.50	3.06	9.81
August	21.50	21.00	17.12	6.93	4.75	14.26
September	30.00	29.93	24.56	8.93	8.00	20.28
October	39.56	38.12	32.50	12.75	11.00	26.78
November	45.37	44.75	40.12	16.68	13.43	32.07
December	30.25	33.50	29.00	13.00	11.31	23.41
January- 2010	12.62	15.50	12.75	6.75	5.50	10.62
February	6.62	8.50	7.50	4.12	3.93	6.13

Table 11. Seasonal incidence of *C. maculatus* on Vermicelli, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Form	Mandya City	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	1.40	1.30	1.25	1.20	1.15	1.26
April	3.68	3.62	3.25	2.43	2.25	3.04
May	4.00	3.70	3.10	2.75	2.37	3.18
June	6.62	6.31	6.20	3.87	2.56	5.11
July	12.93	11.68	11.50	4.68	3.00	8.75
August	20.12	17.50	17.37	6.06	4.31	13.07
September	27.12	24.50	24.18	7.93	6.81	18.10
October	36.00	33.37	32.56	19.81	11.75	26.69
November	40.93	40.43	38.06	15.50	12.43	29.47
December	31.75	30.62	30.5	11.43	10.37	22.93
January- 2010	14.62	13.62	13.06	6.25	4.43	10.39
February	8.87	7.00	6.18	3.00	2.00	5.41

***Tribolium castaneum* Herbst. (Tenebrionidae: Coleoptera)**

The Rust-red flour beetle, *Tribolium castaneum* is small sized, flat and reddish with club shaped antenna (Plate 4d). Grubs construct tunnels and fed as they move through flour and adults fed on the product that has already damaged by other insects.

The incidence of lesser grain borer varied from 1.50 to 61.68 insects/sample at all study locations on fried ragi flour. The incidence level was higher during July to January; relatively low during February and June (Table 12).

Almost similar observations were recorded on Vermicelli and Papad at all locations (Table 13 and 14). The pest incidence varied from 1.50 to 59.62 insects/sample on Vermicelli (Table 13), while it was 1.75 to 56.43 insects/sample on Papad (Table 14). The products like Sandige and Chakali (muruku) were free from *T. castaneum* infestation

***Lasioderma serricorne* Fb. (Anobiidae :Coleoptera)**

The Cigarette beetle, *Lasioderma serricorne* was light brown round beetle, thorax and head bent downward this presents a strongly humped appearance to the insect (Plate 4e). The elytra have minute hairs on them. Antenna is of uniform thickness. The grub is white; both adults and grubs fed freely on all products without webbing; however, few grubs slightly mixed the flour. The incidence of *L. serricone* varied from 1.50 to 60.12 insects/sample at all study locations on Hurihittu. The incidence was maximum during July to January and minimum during February to June at all locations on fried ragi flour (Table 15).

Almost the similar observations were recorded on vermicelli at all locations (Table 16). Further the incidence of *L. serricorne* was not found on Papad, Sandige and Chakali (muruku).



Plate 4a. *Sitophilus oryzae*



Plate 4b. *Corcyra cephalonica*



Plate 4c. *Callosobruchus maculatus*



Plate 4d. *Tribolium castaneum*



Plate 4e. *Lasioderma serricorne*

Plate 4. Insect pests of ragi value added products

Table 12. Seasonal incidence of *T. castaneum* on Hurihittu, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya City	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	3.60	3.25	3.13	2.50	1.50	2.79
April	8.06	6.00	5.50	5.68	2.25	5.49
May	9.43	8.43	6.25	5.81	3.62	6.70
June	13.75	13.12	9.81	6.25	5.12	9.61
July	21.87	21.81	16.56	8.18	7.18	15.12
August	31.87	31.50	26.56	9.75	9.81	21.89
September	43.75	43.00	38.12	12.81	13.68	30.27
October	53.06	52.12	47.25	17.62	17.75	37.56
November	61.68	60.43	55.25	22.62	22.37	44.47
December	43.75	40.75	37.00	16.25	16.00	30.75
January- 2010	18.25	16.68	13.25	7.68	7.63	12.69
February	10.62	10.00	7.50	7.18	5.93	8.24

Table 13. Seasonal incidence of *T. castaneum* on Vermicelli, 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	3.25	3.00	2.50	2.25	1.50	2.50
April	6.75	6.18	6.00	4.75	2.93	5.32
May	6.56	6.00	5.68	4.62	3.00	5.17
June	11.87	9.87	7.56	5.31	4.06	7.73
July	22.31	17.06	10.62	7.06	5.56	12.52
August	30.25	28.50	16.93	8.93	8.50	18.62
September	40.00	39.43	26.56	12.56	12.30	26.17
October	51.06	49.50	39.75	16.18	16.00	34.49
November	59.62	58.25	47.12	21.56	21.25	41.56
December	38.87	37.00	32.87	14.87	13.31	27.38
January- 2010	15.87	14.31	12.37	7.75	6.78	11.41
February	10.00	8.00	6.00	5.00	4.00	6.60

Table 14. Seasonal incidence of *T. castaneum* on Papad2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	2.00	2.25	2.20	2.00	1.75	2.04
April	3.68	3.50	3.30	3.50	3.00	3.39
May	6.50	4.37	4.25	4.00	3.90	4.60
June	9.37	7.87	7.18	4.43	3.56	6.48
July	18.43	12.43	8.25	6.06	5.00	10.03
August	28.00	19.25	10.25	8.18	8.12	14.76
September	36.25	25.25	13.25	11.68	11.00	19.48
October	46.87	30.68	19.56	15.62	15.43	25.63
November	56.43	34.25	24.68	20.68	20.25	31.25
December	40.00	22.87	18.31	12.81	12.22	21.24
January- 2010	14.37	9.75	8.50	7.43	5.87	9.18
February	6.25	7.06	6.80	5.00	4.50	5.92

Table 15. Seasonal incidence of *Lasioderma serricorne* in Hurihittu 2009-10 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	2.25	2.00	1.75	1.50	2.00	1.90
April	7.31	6.75	4.55	4.37	2.50	5.09
May	9.00	7.25	4.81	4.75	3.50	5.86
June	12.18	11.00	7.06	5.25	3.75	7.84
July	19.18	18.37	12.80	7.06	4.25	12.33
August	30.56	30.25	19.37	8.75	6.56	19.09
September	40.06	40.05	26.31	11.43	9.43	25.45
October	51.06	49.50	34.18	15.62	12.06	32.48
November	60.12	57.12	42.42	20.31	15.75	39.14
December	39.82	39.25	31.43	13.62	20.37	28.89
January- 2010	14.37	13.62	13.25	6.56	14.43	12.44
February	8.87	8.75	7.50	5.93	7.43	7.69

4.1.1 Response of insect pests on ragi value added products

The incidence of *S. oryzae* was maximum on Hurihittu (21.36) followed by vermicelli (18.79), papad (16.07) and sandige (15.94). Similarly the incidence of *C. cephalonica* was also maximum on the above products. However, the incidence of *C. maculatus* and *L. serricornis* was noticed only on Hurihittu and Vermicelli; further, *T. castaneum* was recorded only on Hurihittu, Vermicelli and Papad by recording 18.80, 18.71 and 12.83 insects/sample (Table 17).

4.2 Biology of *Corcyra cephalonica* on Hurihittu

Detailed investigation on the biology of the rice meal moth, *C. cephalonica* was carried out on stored broken ragi value added products from August 2009 to May 2010, and the results pertaining to the studies are presented here under.

4.2.1 Eggs

Freshly laid eggs were glistening pearly white in color with rough, irregularly sculptured surface, divided into small uneven areas. The egg was small, somewhat elliptical, with blunted at rounded ends and eggs possessed a minute nipple like protuberance at one end (Plate 5a). Prior to hatching, the bright colour got slightly dim and assumed a slight touch of yellow on third day which developed into a dirty shade on the day of hatching or fourth day. Hatching usually took place in the night or early morning hours.

The larvae eventually emerged by biting through the chorion with its dark mandibles and emerged from the ragged hole bitten at the side of egg through which the head was forced out. The larva took nearly quarter of an hour to work its way to come out. When larva emerged out from egg shell, the empty egg shell collapsed became wrinkled and white in color.

Table 16. Seasonal incidence of *Lasioderma serricorne* on Vermicelli, 2009-1 (pooled data)

Month	Incidence (Mean per sample)					Mean
	Location					
	ZARS store room	V.C. Farm	Mandya city	Hebbal girl's hostel	P.G girl's hostel	
March- 2009	3.00	2.75	2.00	1.75	1.50	2.20
April	5.50	5.30	3.81	3.50	3.00	4.22
May	5.81	5.56	4.18	4.00	2.93	4.49
June	9.87	9.37	6.75	4.37	3.37	6.74
July	18.18	16.37	9.31	5.93	5.56	11.07
August	29.00	27.31	15.31	8.62	7.93	17.63
September	38.70	37.93	24.75	10.62	10.43	24.48
October	48.31	46.25	36.68	15.00	14.50	32.14
November	57.12	54.25	43.75	19.50	19.06	38.73
December	39.56	39.06	36.68	13.56	13.37	28.44
January- 2010	13.56	13.24	12.80	16.81	5.37	12.35
February	7.87	7.00	6.43	6.00	5.00	6.46

Table 17. Response of insect pests on ragi value added products, 2009-10 (pooled data)

Pests	Hurihittu	Vermicelli	Papad	Sandige
<i>S. oryzae</i>	21.36	18.79	16.07	15.94
<i>C. cephalonica</i>	23.99	22.63	20.61	17.13
<i>C. maculatus</i>	13.34	12.28	-	-
<i>T. castaneum</i>	18.80	18.71	12.83	-
<i>L. serricorne</i>	18.52	15.75	-	-

Table 18. Duration of different life stages of *C. cephalonica* on Hurihittu

Stages	Range (days)	Mean \pm SD (days)
Eggs	4-7	4.34 \pm 0.900
Larval instars I	5-7	5.70 \pm 0.823
II	8-9	8.50 \pm 0.527
III	5-6	5.66 \pm 0.516
IV	6-7	6.73 \pm 0.483
V	4-5	4.33 \pm 0.483
VI	9-11	9.82 \pm 0.918
Total larval period	37-45	38.27 \pm 2.357
Pupal period	11-15	11.94 \pm 1.220

Table 19. Dimensions of head capsule, thorax and body length of different larval instars and pupae

Stages	Length (mm)	Width (mm)	
Egg	0.50 - 0.71 (0.65)	0.31- 0.41 (0.36)	
Larval instars	Head capsule width (mm)	Thorax width (mm)	Body length (mm)
I	0.26	0.18	1.28
II	0.31	0.41	2.63
III	0.42	0.81	4.12
IV	0.62	1.07	7.33
V	0.82	1.35	9.53
VI	1.08	1.51	10.95
Pupae	0.87	0.96	10.58

The incubation period ranged from 4 to 7 days (mean 4.34) (Table 18). The egg measured 0.50-0.71mm in its length (average 0.65mm) and 0.31 to 0.41mm in its width (average 0.36mm) (Table 19).

4.2.2 Larva

The larva was cylindrical in shape measuring 1.28 to 10.95 mm from first instar to last instar. It moulted five times and hence passed 6 instars. The complete larval development took place within the cluster or gallery formed by the larva.

4.2.2.1 First instar larva

Freshly hatched larva is light creamish white in colour, with uniform thickness. The head capsule is yellowish white measured 0.26mm width with brownish margin and cervical shield was not very distinct but demarcated as a light yellowish area and epicranium was light brown (Plate 5b). Frons pale brown, labrum light yellowish brown, mandibles were brown with deep brown edges having three teeth and region of the eye was dark brown in colour. The setae whitish; the dorsal ones were as long as the width of the body. The anal plate was inconspicuous.

On emergence from the egg, larva was active and able to wander in search of food and begin to feed almost immediately after searching food. During the stage, larva was able to live without food for a day or two. When touched, they curl themselves formed semicircle. On reaching the food they settle down in silken shelters and rapidly made cluster by webbing broken products, mixing with excreta. The moulting was identified by casted head capsule which was minute and hard.

The larval duration ranged from 5 to 7 days with an average of 5.70 ± 0.823 days (Table 18) and it measured 0.26mm in head capsule width, 0.18mm thorax width and 1.28mm body length (Table 19).

4.2.2.2 Second instar larva

The second instar larva closely resembled the first instar larva. It was dirty white in colour (Plate 5c). This stage was distinguished from previous stage by the deep yellowish brown colour of the head capsule, arrangement of setae was somewhat altered, it leaps forward and was equally alert in moving backwards.

The duration ranged from 8 to 9 days with a mean of 8.50 ± 0.527 days (Table 18). The larva measured 0.31mm in head capsule width, 0.41mm thorax width and 2.63mm body length (Table 19).

4.2.2.3 Third instar larva

The third instar larva differed markedly from preceding two stages in the head capsule which is dark brown in color. The thoracic shield and anal plate are become more distinct (Plate 5d). The larva fed under dense silken cylindrical covering, and from this stage, it was difficult to follow the individual development, since they have to be disturbed from the galleries in the course of search for casted head capsule.

The larval duration ranged from 5 to 6 days with an average of 5.66 ± 0.516 days (Table 18). The larva measured 0.42mm in head capsule width, 0.81mm thorax width and 4.12mm body length (Table 19).

4.2.2.4 Fourth instar larva

The fourth instar larva was dirty white in color with a dark border line and mandibles were darker and prominent and the eyes conspicuously dark (Plate 5e). The larva had a wavy dirty streak along the dorsal line on the abdomen, displaying alimentary canal through transparent cuticle.



Plate 5a. Eggs



Plate 5b. First instar larva



Plate 5c. Second instar larva



Plate 5d. Third instar larva



Plate 5e. Fourth instar larva



Plate 5f. Fifth instar larva

Plate 5. Immature stages of *Corcyra cephalonica*

The silken gallery was thick and studded with numerous pellets of excreta, frass and products. The larva was generally less active than in the previous stages and seeks hiding places more eagerly when exposed to light.

The duration of this stage ranged from 6 to 7 days with a mean of 6.73 ± 0.483 days (Table 18). The larva measured 0.62mm head capsule width, 1.07mm thorax width and 7.33mm body length (Table 19).

4.2.2.5 Fifth instar larva

In the fifth instar larva, the hairs or setae were brownish in color and the tubercles arise conspicuously. The cuticle was somewhat rough or granulated (Plate 5f). The mandibles and head capsule was darker in colour than in the preceding stage and lived in a denser covering. In this stage, larval duration ranged from 4 to 5 days with a mean of 4.33 ± 0.483 days (Table 18). The larva measured 0.82mm head capsule width, 1.35mm thorax width and 9.53mm body length (Table 19).

4.2.2.6 Sixth instar larva

The larva was more or less cylindrical in shape, slightly tapered towards ends and dirty white in colour. The rounded head capsule was reddish brown in colour. Thoracic shield was yellowish brown and anal plate dusky brown colour. Head distinctly less broader than the thoracic shield, which was partly retracted (Plate 5g). The mandibles were prominent with distinct dark teeth. Thoracic legs were five segmented and jointed. The tarsus was darker in color and terminated in a curved hook or the claw.

Prolegs creamy white in colour, located on abdominal segments of 3 to 6 and crowned with a complete circle alternated with short crochets. The anal prolegs were different and do not have complete circle. There were nine spiracles and more or less circular in form, clean and prominent with a dark edge, the prothoracic and last abdominal spiracles larger than the others. Setae were brownish and each segment had

four longitudinal rows along the body. The setae near the first and the eight abdominal spiracles have at their bases an incomplete encircling of dark ring. Full grown larva was concealed and fed in a silken web. The larva wandered around in search of place before pupation.

This stage ranged from 9 to 11 days with a mean of 9.82 ± 0.918 days (Table 18). The larva measured 1.08mm in head capsule width, 1.51mm thorax width and 10.95mm body length (Table 19).

4.2.3. Pupa

The pupa was deep leathery brown in colour and was enclosed in a cocoon (Plate 5h). The cocoon was more or less elongate and thinly woven, with elliptical space at one end, which is the provision for the adult emergence.

The white silken structure was covered with small and large pieces of broken products, debris and excrement. After the cocoon was spun, larva became inactive and shrinks in size. This pre-pupal condition lasted for a day or at most two. The female pupa was larger than male pupa. The pupal duration lasted to 11 to 15 days with a mean of 11.94 ± 1.22 days (Table 18). The pupa measured 0.87mm head capsule width, 0.96mm thorax width and 10.58mm body length (Table 19).

4.2.4 Adults

The adults were comparatively small moths, exhibiting considerable variation in size. They were uniformly dark grey in colour with a few dark hair lines. The sexes too were dissimilar in size, the females were ordinarily larger. The head was elongate with snout like projection of labial palpi in females whereas projection was less conspicuous and blunted in males (Plate 6).



Plate 5g. Sixth instar larva



Plate 5h. Pupa

Plate 5. Immature stages of *corcyra cephalonica*



Plate 6. Male and Female of *C. cephalonica* Stainton



Plate 7. Larva feeding on Hurihittu

The measurement across the expanded wings of female was 14 to 23mm, with an average of 19mm and in males: 14 to 18mm, with an average of 17mm. Adults emerged from the silken cocoon through an irregular exit hole and they do not require any nourishment.

4.2.5 Flight

The flight took place only when actually disturbed, being rather sluggish. The flight itself was to a certain extent slow, clumsy and unsteady and often takes in zigzag direction and moths were capable of sustaining the flight for some time and soon after the adults returned to resting position. The adult moths were less phototropic and in presence of strong light they took flight leisurely.

4.2.6 Mating

Mating was observed during the day time. The females began courtship 12 to 14 hours after adult emergence, which lasted for an hour, when males were identified by darting or shaking their wings and frequently pair with females in a few minutes. Mating period observed ranged from 55 to 120 minutes with a mean of 85.55 ± 22.29 minutes (Table 20). Repeated mating between a pair was uncommon.

4.2.7 The pre-oviposition period

The period ranged 1 to 2 days with a mean of 1.35 ± 0.32 days (Table 20). Prior to egg laying, the female moth produced certain amount of frass.

4.2.8 Ovipositional period and fecundity

The number of eggs laid per day by the female varied. The eggs were usually laid at night, but occasionally during the day also. The eggs were generally laid singly or sometimes in groups which contained 3 to 4 eggs each in oviposition cage. The eggs were

laid on the surface of the products when moths left on food. The fecundity varied from 254 to 392 eggs with a mean of 283 ± 37.82 eggs per female. The ovipositional period ranged from 5 to 8 days with a mean of 6.40 ± 1.40 days (Table 20). Presence of host was not quite essential for egg laying by the adult female.

4.2.9 Effect of adult feeding on fecundity and longevity of *C. cephalonica*

Fecundity of the females which have been provided with 50% honey solution was more fecundity ranged from 300 to 461 eggs with a mean of 385 ± 50.54 eggs per female compared to the females which were not provided without any food (250 to 430 eggs with a mean of 318.8 ± 85.04 eggs per female). The adult female longevity in presence of 50% honey solution lasted 8 to 14 days with a mean of 8.50 ± 1.05 days, and in the absence of food, its longevity ranged 6 to 13 days with a mean of 8.23 ± 2.65 days (Table 21). In unmated male adult longevity ranged between 8 to 12 days with a mean of 9.88 ± 1.77 days and mated males lived for 5 to 18 days with a mean of 7.43 ± 0.916 days; similarly, the mated females lived for 8 to 16 days with a mean of 11.62 ± 3.07 days (Table 20).

4.2.10 Infestation behaviour and nature of damage of *C. cephalonica*

4.3.10.1 Nature of damage of *C. cephalonica*

Newly emerged larva after hatching was very active and started crawling in search of food. After reaching the food, it started scraping or webbing the product. When it was a damaged one, it started feeding on the product. Subsequently, the faecal pellets were used by the larva to form a cluster of products and pest was found feeding inside the cluster.

Later stage of infestation reveals dense white silken cocoon with damaged products, frass and excreta matted together. Pupation occurred inside the white silken structure.

Table 20. Duration of different parameters of biology of *C. cephalonica* on Hurihittu

Duration	Range	Mean \pm SD
Total developmental period (egg + larva + pupa) (Days)	52 – 67	59.35 \pm 6.12
Mating period (minutes)	55 – 120	85.55 \pm 22.29
Pre-ovipositional period (days)	1 – 2	1.35 \pm 0.32
Ovipositional period (days)	5 – 8	6.40 \pm 1.49
Postoviposition period (days)	2 – 3	2.50 \pm 0.52
Adult longevity (days)		
a. Virgin males	8 - 12	9.88 \pm 1.77
b. Mated males	5 – 18	7.43 \pm 0.91
Mated female longevity	8 – 16	11.62 \pm 3.07
Fecundity	254 – 392	283 \pm 37.82

Table 21. Effect of adult feeding on fecundity and longevity of *C. cephalonica*

	Total fecundity (number of eggs per female)		Longevity (days)	
	Range	Mean \pm SD	Range	Mean \pm SD
Females provided with 50% honey solution	300-461	385 \pm 50.54	8-14	8.50 \pm 1.05
Females not provided with any food	250-430	318.8 \pm 85.04	6- 13	8.23 \pm 2.65

Later, the adults emerged from the product clusters. Newly emerged adults underwent mating for 55 to 120 minutes and finally found searched suitable places for oviposition.

Larva was the only damaging stage and fed the product, further larvae feed voraciously (Plate 7).

4.2.10.2 Food requirement for total larval development

The entire larval development occurred by feeding on Hurihittu. The quantity of Hurihittu required for the entire larval development varied from 0.2 to 0.5 g (Table 22).

4.2.11 Influence of different hosts of ragi value added products viz., Hurihittu, Vermicelli, Papad and Sandige on the biology of *C. cephalonica*

The data on different parameters on biology of *C. cephalonica* is presented in Table 23. The data revealed that the incubation period on different ragi value added products, viz., Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku) was 4.30 days in all the hosts. There was no significant influence of hosts on hatching period (Table 23).

The shortest larval period of 38.20 days was observed on Hurihittu followed by Vermicelli (47.20), Papad (48.90) and Sandige (49.07); further all the treatments differed significantly with each other (Table 23).

The shortest pupal period of 11.92 days was observed on Hurihittu. While the longest pupal period of 12.80 days was observed on Sandige and differed significantly with rest of the treatments (Table 23).

The longevity of male varied from 7.40 to 8.20 days while that of female from 11.60 to 12.40 days. The longevity of adult male was also minimum (7.40) on Hurihittu followed

by Vermicelli (7.70), Papad (8.00) and Sandige(8.20). Similarly, the longevity **Table 22.**

Consumption pattern of Hurihittu by *C. cephalonica*

Sl. No.	Weight of Hurihittu consumed by larvae	Sl. No.	Weight of Hurihittu consumed by larvae
1.	0.5	16.	0.3
2.	0.2	17.	0.0
3.	0.3	18.	0.5
4.	0.3	19.	0.4
5.	0.5	20.	0.3
6.	0.4	21.	0.3
7.	0.5	22.	0.5
8.	0.4	23.	0.3
9.	0.5	24.	0.3
10.	0.5	25.	0.2
11.	0.4	26.	0.0
12.	0.5	27.	0.3
13.	0.5	28.	0.3
14.	0.4	29.	0.3
15.	0.4	30.	0.3
Mean= 0.36			
SD=0.106			

Note: 3 g Hurihittu per vial

of female was lowest (11.60) in Hurihittu, followed by Vermicelli, Papad and Sandige, further all the treatments differed significantly with each other (Table 23).

The fecundity of the moth was maximum (283.00) when reared on Hurihittu followed by Vermicelli (152.80), Papad (119.80) and Sandige (92.90), which differed significantly with each other (Table 23).

The total developmental period (egg+larva+pupa) was also recorded. The results indicated that the shortest developmental period was recorded on Hurihittu (55.20) followed by Vermicelli (64.00), Papad (68.30) and Sandige (70.32). The larvae of *C. cephalonica* did not feed on Chakali (Muruku), indicated no preference; hence all the figures have showed zero feeding (Table 23).

4.3 Shelf life of ragi value added products

The results pertaining to shelf life of ragi value added products *viz.*, Hurihittu, Vermicelli, Papad, Sandige and Chakali when stored in different containers and duration are presented here under.

4.3.1. Shelf life of Hurihittu

4.3.1.1 *C. cephalonica*

The Hurihittu stored in cloth bag (T₁) infested with *C. cephalonica* at 30 days, recorded 4.00 insects followed by 22.00, 34.00, 55.00, 63.00 and 74.25 insects at 60, 90, 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene cover (T₂) recorded the infestation of (10.00) at 120 days followed by 15 and 20 insects at 150 and 180 days respectively, which also differed significantly.

When the produce stored in glass container (T₃) recorded the incidence of 2.25 insects at 150 days and differed significantly. Similarly, the produce when stored in mud

Table 23. Comparison of different parameters of *C. cephalonica* on ragi value added products

Sl.No.	Food materials	Incubation period (days)	Larval period (days)	Pupal period (days)	Longevity (days)		Fecundity	Total developmental period (days)
					males	Females		
1	Hurihittu	4.30 ^e (2.17)	38.20 ^d (6.22)	11.94 ^d (3.52)	7.40 ^d (2.81)	11.60 ^d (3.47)	283.00 ^a (16.83)	59.30 ^d (7.46)
2	Vermicelli	4.30 ^d (2.17)	47.20 ^c (6.90)	12.30 ^c (3.57)	7.70 ^c (2.86)	11.72 ^c (3.49)	152.80 ^b (12.38)	64.00 ^c (8.03)
3	Papad	4.30 ^c (2.17)	48.90 ^b (7.02)	12.60 ^b (3.61)	8.00 ^b (2.91)	11.90 ^b (3.52)	119.80 ^c (10.96)	68.30 ^b (8.29)
4	Sandige	4.30 ^b (2.17)	49.07 ^a (7.04)	12.80 ^a (3.64)	8.20 ^a (2.94)	12.40 ^a (3.59)	92.90 ^d (9.66)	70.32 ^a (8.41)
5	Chakali*	4.30 ^a (2.17)	0.00 ^e (0.70)	0.00 ^e (0.70)	0.00 ^e (0.70)	0.00 ^e (0.70)	0.00 ^e (0.70)	0.00 ^e (0.70)

*Larvae of *C. cephalonica* did not feed on chakali; hence all the figure showed zero feeding

containers (T₄) the *C. cephalonica* incidence was 17.00 at 90 days followed by 30, 45 and 52 insects at 120, 150 and 180 days respectively and differed significantly. However, the produce stored in steel container(T₅) is free from *C. cephalonica* attack till 120 days; however, recorded lower (4.00) insects at 180 days.

Among the storage containers, the produce stored in cloth bag (T₁) attacked by *C. cephalonica* at 30 days. While in other containers, no insect pest attack and differed significantly. Almost, the similar trend was observed among the treatments at 60 days after storage. At 90 days cloth bag (T₁) recorded the maximum (34) insects followed by mud container (T₄) and differed significantly while there was no incidence in other treatments. Similarly at 120 days, cloth bag (T₁) recorded the maximum (55) *C. cephalonica* attack followed by mud container (T₄) and polythene cover (T₂) and differed significantly. There was no incidence of *C. cephalonica* in glass (T₃) (0.00) and steel containers (T₅) (0.00). At 150 and 180 days also the produce stored in cloth bag (T₁) recorded the maximum number of insects followed by mud container (T₄) and polythene cover (T₂). There was less incidence in glass (T₃) and steel containers (T₅) and differed significantly (Table 25).

4.3.1.2 *S. oryzae*

The Hurihittu stored in cloth bag (T₁) infested with *S. oryzae* at 30 days, recorded 4.25 insects followed by 22.50, 37.00, 50.00, 57.00 and 65.00 insects at 60, 90, 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene covers (T₂) recorded (12.00) insects at 120 days followed by 20 and 24 insects at 150 and 180 days respectively, which also differed significantly.

When the same produce stored in glass container (T₃) recorded 5.00 insects at 180 days and was free from insect attack till 150 days; later incidence was noticed at 180 days, and recorded 5 insects, which differed significantly with all duration periods. The produce Hurihittu when stored in mud containers (T₄) recorded 14.25 insects at 90 days followed by 25, 30 and 35 insects at 120, 150 and 180 days respectively and differed

significantly. However, the produce stored in steel container (T₅) was free from *S. oryzae* attack till 150 days. However recorded lower (3.00) incidence at 180 days and differed significantly.

Among the different storage structures, the produce stored in cloth bag(T₁) attacked by *S. oryzae* at 30 days, while in other containers, no incidence of insect attack and differed significantly. Almost, the similar trend was observed among the storage structures at 60 days after storage. At 90 days cloth bag (T₁) recorded the maximum of 37 insects followed by mud container (T₄) and differed significantly while there was no infestation in other treatments. Similarly, at 120 days, cloth bag (T₁) recorded the maximum (50.00) *S. oryzae* attack followed by mud container (T₄) (25.00) and polythene cover (T₂) (12.00) and differed significantly. There was no incidence of *S. oryzae* both in glass (T₃) and steel containers (T₅) (Table 24).

Almost the same trend was observed at 150 after the storage in all the storage containers. At 180 days cloth bag (T₁) recorded the maximum 65 insects followed by mud container (T₄) (35) and polythene cover (T₂) (24). There was less incidence in (T₅) (3.00) and (T₃) (5.00) and differed significantly (Table 24).

4.3.1.3 *T. castaneum*

The Hurihittu stored in cloth bag (T₁) infested with *T. castaneum* at 30 days, recorded 3.00 insects followed by 5.00, 10.00, 25.00, 38.00 and 52.00 insects at 60, 90, 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene covers (T₂) recorded (2.00) insects at 120 days followed by 7.00 and 11.25 insects at 150 and 180 days respectively which also differed significantly. When the produce stored in glass container attacked at 180 days and differed significantly.

The produce when stored in mud containers (T₄) the Hurihittu incidence was 2.00 at 90 days followed by 6, 10 and 26 insects respectively at 120, 150 and 180 days respectively and differed significantly. However, the produce stored in steel container

Table 24. Shelf life of Hurihittu against *C. cephalonica*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>C. cephalonica</i>	T₁	0.00 (0.70)	4.00 (2.11)	22.00 (4.74)	34.00 (5.87)	55.00 (7.44)	63.00 (7.96)	74.25 (8.64)	36.03 (5.35)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	10.00 (3.23)	15.00 (3.93)	20.00 (4.52)	6.42 (2.07)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.25 (1.63)	6.00 (2.54)	1.17 (1.10)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	17.00 (4.18)	30.00 (5.52)	45.00 (6.74)	52.00 (7.24)	20.57 (3.68)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	4.00 (2.11)	0.85 (1.03)
	Mean	0.00 (0.70)	0.80 (0.98)	4.40 (1.51)	10.20 (2.43)	19.00 (3.52)	25.45 (4.37)	31.25 (5.01)	
		F- value*							
	SEM± CD@P=0.01	A 0.13 0.36		B 0.13 0.36			AB 0.29 0.81		

Figures in parenthesis were $\times+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

Table 25. Shelf life of Hurihittu against *S. oryzae*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>S. oryzae</i>	T₁	0.00 (0.70)	4.25 (2.17)	22.50 (4.78)	37.00 (6.12)	50.00 (7.10)	57.00 (7.58)	65.00 (8.09)	33.67 (5.22)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	12.00 (3.53)	20.00 (4.52)	24.00 (5.04)	8.14 (2.27)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	5.00 (2.34)	0.71 (0.94)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	14.25 (3.83)	25.00 (5.04)	30.00 (5.52)	35.00 (5.95)	14.89 (3.21)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.00 (1.86)	0.042 (0.87)
	Mean	0.00 (0.70)	0.85 (0.99)	4.50 (1.52)	10.25 (2.41)	17.40 (3.42)	21.40 (3.80)	26.60 (4.66)	
	F- value*								
	SEM± CD@P=0.01	A 0.20 0.56			B 0.17 0.48			AB 0.45 1.27	

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

was free from *T. castaneum* attack till 150 days; further recorded lower (2.00) incidence at 180 days.

Among the storage containers, the produce stored in cloth bag (T₁) attacked by *T. castaneum* at 30 days. While in other containers, no insect pest attack and differed significantly. Almost the similar trend was observed among the treatments at 60, 90, 120 and 150 days after storage. Cloth bag (T₁) recorded the maximum of 10 insects, followed by mud container (T₄) (2.00) at 90 days and differed significantly; while there was no infestation in other treatments. Similarly at 120 days, Cloth bag (T₁) recorded the maximum (25.00) *T. castaneum* attack followed by mud container (T₄) (6.00) and polythene cover (T₂) (2.00) and differed significantly. There was no incidence recorded in glass container (T₃) (0.00) and steel container (T₅) (0.00). Similarly both at 150 and 180 days, Cloth bag (T₁) recorded maximum insects followed by mud container (T₄) and polythene cover (T₂) and differed significantly; and there was no incidence in glass container (T₃) and steel container (T₅) further differed significantly (Table 26).

4.3.2 Shelf life of Vermicelli

4.3.2.1 *C. cephalonica*

The Vermicelli stored in cloth bag (T₁) infested with *C. cephalonica* at 30 days recorded 3.00 insects followed by 15.00, 23.00, 31.00, 43.00, 52.00 and 23.85 insects at 60, 90, 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene covers (T₂) recorded (2.25) insects at 120 days followed by 12.00 and 23.25. At 150 and 180 days respectively; and all these differed significantly. Similarly, when the produce stored in glass container (T₃) was free from insect incidence till 120 days; later the incidence was 1.00 and 5.00 at 150 and 180 days and differed significantly.

The produce stored in mud container (T₄) was also free from *C. cephalonica* attack till 60 days; Later the incidence of 5.00 insects was recorded at 90 days followed

Table 26. Shelf life of Hurihittu against *T. castaneum*

Insect species	Storage Structure	Duration (days)							Mean
		0	30	60	90	120	150	180	
<i>T. castaneum</i>	T₁	0.00 (0.70)	3.00 (1.86)	5.00 (2.34)	10.00 (3.23)	25.00 (5.04)	38.00 (6.20)	52.00 (7.24)	19.00 (3.80)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	7.00 (2.73)	11.25 (3.42)	2.89 (1.56)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	0.57 (0.90)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	6.00 (2.54)	10.00 (3.23)	26.00 (5.14)	6.28 (2.08)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	0.28 (0.82)
	Mean	0.00 (0.70)	0.60 (0.93)	1.00 (1.03)	2.40 (1.38)	6.60 (2.11)	11.00 (2.71)	19.05 (3.89)	
		F- value*							
		A			B			AB	
	SEM±	0.12			0.10			0.27	
	CD@P=0.01	0.33			0.28			0.75	

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₄. Mud container

T₂. Polythene cover

T₅. Steel container

T₃. Glass contain

by 16.00, 22.00 and 29.00 insects at 120, 150 and 180 days respectively and differed significantly. Further, the produce stored in steel container (T₅) was free from *C. cephalonica* attack till 150 days; later recorded lower (1.00) insects at 180 days.

Among the storage containers, the produce stored in the cloth bag (T₁) attacked by *C. cephalonica* at 30 days, while in other containers, there was no pest attack or incidence and differed significantly. Almost, the similar trend was observed among the treatments at 60 days after storage. At 90 days, cloth bag (T₁) recorded the maximum of 23 insects followed mud container (T₄) (5.00) and differed significantly, while there was no infestation in other treatments. Similarly at 120 days, cloth bag (T₁) (31.10) recorded the maximum *C. cephalonica* attack followed by mud container (T₄) (16.00) and polythene cover (T₂) (2.25) and differed significantly while there was no infestation in glass container (T₃) and steel container (T₅). Similarly at 150 and 180 days, cloth bag (T₁) recorded the maximum incidence followed by mud container (T₄), polythene cover (T₂) and glass container (T₃) and differed significantly. There was no incidence in steel container (T₅) and differed significantly (Table 27).

4.3.2.2 *S. oryzae*

The Vermicelli stored in cloth bag was infested with *S. oryzae* at 60 days and recorded 3.25 insects followed by 6.00, 16.25, 24.00 and 43.00 insects at 90, 120, 150 and 180 days respectively. While the same produce stored in polythene cover recorded (2.00) insects at 120 days followed by 10.00 and 17.00 insects at 150 and 180 days respectively which differed significantly.

When the produce stored in glass container recorded 4.00 insects at 180 days and differed significantly with others. The produce when stored in mud containers recorded (4.00) was recorded at 120 days followed by 16.00 and 23.00 insects at 150 and 180 days respectively, and differed significantly. However, when the produce was stored in steel container the produce was free from the insect attack till 180 days and recorded lower (2.00) incidence.

Table 27. Shelf life of Vermicelli against *C. cephalonica*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>C. cephalonica</i>	T ₁	0.00 (0.70)	3.00 (1.86)	15.0 (3.93)	23.0 (4.84)	31.0 (5.61)	43.0 (6.59)	52.0 (7.24)	23.85 (4.40)
	T ₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.25 (1.63)	12.0 (3.53)	23.25 (4.87)	5.35 (1.83)
	T ₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	5.25 (2.39)	0.89 (1.01)
	T ₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	5.00 (2.34)	16.00 (4.06)	22.00 (4.74)	29.00 (5.43)	10.28 (2.67)
	T ₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	0.14 (0.77)
	Mean	0.00 (0.70)	0.60 (0.93)	3.00 (1.35)	5.60 (1.86)	9.85 (2.54)	15.60 (3.35)	22.10 (4.22)	
		F- value*							
		A		B		AB			
	SEM±	0.13		0.11		0.30			
	CD@P=0.01	0.37		0.31		0.84			

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₄. Mud container

T₂. Polythene cover

T₅. Steel container

T₃. Glass container

Among the storage containers, the produce stored in cloth bag (T₁) was infested at 60 days by *S. oryzae*, while in other containers, there was no insect attack and differed significantly. Almost, the similar trend was observed among the treatments at 90 days, 120 days after storage. Similarly at 150 and 180 days, cloth bag (T₁) recorded the maximum *S. oryzae* attack followed by mud containers (T₄) and polythene cover (T₂) and differed significantly. In case of glass (T₃) and steel containers (T₅) no insects were recorded (Table 28).

4.3.2.3 *T. castaneum*

The Vermicelli stored in cloth bag (T₁) infested with *T. castaneum* at 120 days recorded 11.00 insects followed by 14.00 and 22.00 insects at 150 and 180 days respectively and differed significantly. While the same produce stored in polythene covers (T₂) recorded (3.00) insects at 150 days followed by 7.75 at 180 days, which also differed significantly.

When the produce stored in glass container (T₃) infestation was observed after 180 days and differed significantly. The produce when stored in mud containers (T₄) recorded 4.00 at 150 days followed by 15.00 insects at 180 days respectively and differed significantly. Similarly, the produce stored in steel container (T₅) was found to be free from the attack of *T. castaneum*. However, lower (0.50) incidence was recorded at 180 days.

Among the storage containers, the produce stored in clothe bag (T₁) attacked at 120 days by *T. castaneum*. While in other containers, no insect pest attack was noticed and differed significantly. Similarly, at 150 and 180 days also , T₁ recorded the maximum insects followed by T₄ and T₂ and differed significantly. While, there was no infestation in other treatments. Less infestation was observed in case of glass (T₃) and steel containers (T₅) (Table 29).

Table 28. Shelf life of Vermicelli against *S. oryzae*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>S. oryzae</i>	T₁	0.00 (0.70)	0.00 (0.70)	3.25 (1.89)	6.00 (2.54)	16.25 (4.09)	24.00 (4.94)	43.00 (6.59)	13.21 (3.07)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	10.00 (3.23)	17.00 (4.18)	4.14 (1.68)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	0.57 (0.90)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	16.00 (4.06)	23.00 (4.84)	6.14 (1.97)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	0.28 (0.82)
	Mean	0.00 (0.70)	0.00 (0.70)	0.65 (0.94)	1.20 (1.07)	4.45 (1.83)	10.00 (2.73)	17.80 (3.86)	
		F- value*							
		A		B		AB			
	SEM±	0.13		0.10		0.29			
	CD@P=0.01	0.36		0.30		0.81			

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

Table 29. Shelf life of Vermicelli against *T. castaneum*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>T. castaneum</i>	T₁	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	11.00 (3.38)	14.00 (3.80)	22.00 (4.74)	6.71 (2.10)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.00 (1.86)	7.75 (2.87)	1.53 (1.18)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.25 (1.92)	0.46 (0.88)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	15.00 (3.93)	2.71 (1.36)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.50 (0.96)	0.07 (0.74)
	Mean	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.20 (1.24)	4.20 (1.83)	9.70 (2.88)	
		F- value*							
		A			B			AB	
	SEM±	0.08			0.07			0.19	
	CD@P=0.01	0.24			0.21			0.55	

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

4. 3.3 Shelf life of Papad

4.3.3.1 *C. cephalonica*

The papad stored in cloth bag was infested with *C. cephalonica* at 30 days and recorded 2.00 insects, followed by 8.00, 16.00, 22.00, 26.00 and 40.00 insects at 60, 90, 120, 150 and 180 days respectively. While the same produce stored in polythene cover recorded the incidence of 2.00 insects at 120 days followed by 8 and 12 insects at 150 and 180 days; further, differed significantly.

When the produce stored in glass container, it was noticed 3.25 insects at 180 days and differed significantly. The produce when stored in mud container recorded 40 insects at 90 days followed by 8.00, 12.00 and 18.00 insects at 120, 150 and 180 days respectively and differed significantly. However, the produce stored in steel container was found to be free from *C. cephalonica* attack till 150 days; even after 180 days it was recorded lower (1.00) incidence.

Among the storage containers, the produce stored in cloth bag (T₁) was attacked by *C. cephalonica* at 30 days. While in other containers, no insect pest attack was observed and differed significantly. Almost similar trend was observed among other treatments at 60 days after storage. At 90 days cloth bag (T₁) recorded the maximum 16 insects followed by mud container (T₄) (4.00) and differed significantly; while there was no infestation in other treatments. Similarly at 120 days, Cloth bag (T₁) recorded the maximum attack of *C. cephalonica* followed by mud container (T₄) and polythene cover (T₂) and differed significantly. Further there was no record of insects in glass (T₃) and steel containers (T₅). Almost the same trend was observed at 150 and 180 days after the storage in all the storage containers. There was less incidence in glass (T₃) and steel containers (T₅) and differed significantly (Table 30).

Table 30. Shelf life of Papad against *C. cephalonica*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>C. cephalonica</i>	T ₁	0.00 (0.70)	2.00 (1.56)	8.00 (2.91)	16.00 (4.06)	22.00 (4.14)	26.00 (5.14)	40.00 (6.36)	16.28 (3.64)
	T ₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	8.00 (2.91)	12.00 (3.53)	3.14 (1.54)
	T ₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.25 (1.92)	0.46 (0.88)
	T ₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	8.00 (2.91)	12.00 (3.53)	18.00 (4.50)	6.00 (2.14)
	T ₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	0.14 (0.77)
	Mean	0.00 (0.70)	0.40 (0.87)	1.60 (0.94)	4.00 (1.65)	6.40 (2.12)	9.20 (2.60)	14.85 (3.46)	
		F- value*							
	SEM± CD@P=0.01	A 0.12 0.33		B 0.10 0.28			AB 0.27 0.75		

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

4.3.3.2. *S. oryzae*

The papad stored in cloth bag infested with *S. oryzae* at 60 days, recorded 5.00 insects followed by 10.00, 12.75, 15.75 and 30.00 insects at 90, 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene cover recorded the incidence of (3.00) insects at 120 days followed by 8.00 and 13.00 insects at 150 and 180 days respectively and differed significantly (Table 31).

When the produce stored in glass container, it was free from pest incidence till 120 days; later, the incidence of 14.00 and 7.25 insects at 150 and 180 days and differed significantly. The produce when stored in mud container recorded 4.00 insects at 90 days followed by 11.00, 17.00 and 22.00 insects at 120, 150 and 180 days respectively and differed significantly. However the produce stored in steel container was free from *S. oryzae* attack till 150 days: later, recorded the lower insects (2.00) at 180 days (Table 31).

Among the storage containers, the produce stored in cloth bag (T₁) attacked at 60 days by *S. oryzae* while in other containers, no insect pest attack and differed significantly. At 90 days, cloth bag (T₁) recorded the maximum 10.00 *S. oryzae* attack followed by mud container (T₄) (4.00) and differed significantly while there was no infestation in other treatments. Similarly, at 120 days, the cloth bag (T₁) recorded the maximum 12.75 insects followed by mud container (T₄) (11.00) and polythene cover (T₂) (3.00) and differed significantly; while there was no infestation in other treatments. Almost the same trend was observed at 150 and 180 days also; and recorded the maximum insects in cloth bag (T₁) followed by mud container (T₄) and polythene cover (T₂) and less insects were recorded in glass container (T₃) and differed significantly, while there was no infestation in other treatments (Table- 31).

Table 31. Shelf life of Papad against *S. oryzae*

Insect species	Storage Structure	Duration (days)							
		0	30	60	90	120	150	180	Mean
<i>S. oryzae</i>	T₁	0.00 (0.70)	0.00 (0.70)	5.00 (2.34)	10.00 (3.23)	12.75 (3.63)	15.75 (4.02)	30.00 (5.52)	10.50 (2.88)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.00 (1.86)	8.00 (2.91)	13.00 (3.67)	3.42 (1.61)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	7.25 (2.77)	1.17 (1.07)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	11.00 (3.38)	17.00 (4.18)	22.00 (4.74)	7.71 (2.36)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	0.28 (0.82)
	Mean	0.00 (0.70)	0.00 (0.70)	1.00 (1.03)	2.80 (1.49)	5.35 (2.06)	8.35 (2.60)	14.85 (3.65)	
	F- value*								
	SEM± CD@P=0.01	A 0.12 0.34			B 0.10 0.29			AB 0.27 0.77	

Figures in parenthesis were $\times+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

4.3.3.3 *T. castaneum*

Papad stored in cloth bag recorded the incidence of 4.00 insects at 90 days, followed by 7.25, 15.00 and 18.00 insects at 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene cover recorded the infestation of (1.00) insect at 120 days followed by 3.00 and 6.00 insects at 150 and 180 days which also differed significantly.

When the produce stored in glass container recorded 3.25 insects at 180 days and differed significantly with rest of the treatments. The produce when stored in mud container recorded the incidence of 3.00 insects at 90 days followed by 6.00, 8.00 and 10.00 insects at 120, 150 and 180 days respectively and differed significantly. However, the produce stored in steel container is free from *T. castaneum* attack till 150 days; later, recorded lower (0.50) insects at 180 days (Table 32).

Among the storage containers, the produce stored in cloth bag (T₁) and mud container (T₄) attacked at 90 days by *T. castaneum*, while in other containers, no insect pest attack and differed significantly. At 120 and 150 days cloth bag (T₁) recorded the maximum incidence followed by mud container (T₄) and polythene cover (T₂), further, differed significantly; while there was no infestation in glass container (T₃) and steel container (T₅). Similarly at 180 days, cloth bag (T₁) recorded the maximum *T. castaneum* attack followed by mud container (T₄) and polythene cover (T₂) and differed significantly (Table 32).

4.3.4 Shelf life of Sandige

4.3.4.1 *C. cephalonica*

The sandige stored in cloth bag infested with *C.cephalonica* recorded 2.00 insects at 90 days followed by 5.75, 9.75 and 15.00 insects at 120, 150 and 180 days respectively and differed significantly. While the same produce stored in polythene cover recorded the infestation of 1.00 at 150 days followed by 5.00 adults at 180 days, which differed

Table 32. Shelf life of Papad against *T. castaneum*

Insect species	Storage Structure	Duration (days)							Mean
		0	30	60	90	120	150	180	
<i>T. castaneum</i>	T₁	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	4.00 (2.11)	7.25 (2.77)	15.00 (3.93)	18.00 (4.30)	6.32 (2.17)
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	3.00 (1.86)	6.00 (2.54)	1.42 (1.20)
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.25 (1.92)	0.46 (0.88)
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	3.00 (1.86)	6.00 (2.54)	8.00 (2.31)	10.00 (3.23)	3.85 (1.87)
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.50 (0.96)	0.07 (0.74)
	Mean	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.40 (1.21)	2.85 (1.58)	5.20 (2.02)	7.55 (2.59)	
			F- value*						
	SEM± CD@P=0.01	A 0.10 0.30			B 0.09 0.25		AB 0.24 0.67		

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₄. Mud container

T₂. Polythene cover

T₅. Steel container

T₃. Glass container

significantly. When the produce stored in glass container recorded low incidence (2.00) at 180 days and differed significantly.

The produce when stored in mud containers recorded the incidence of 2.25 insects at 90 days followed by 4.00, 8.00 and 11.00 insects at 120, 150 and 180 days respectively and differed significantly. However, the produce stored in steel was free from *C.cephalonica* attack, even up to 180 days.

Among the storage containers, the produce stored in cloth bag (T₁) attacked at 90 days by *C. cephalonica*, while in other containers, no insect attack and differed significantly. At 90 days, cloth bag (T₁) recorded the maximum (2.00) insects followed by mud container (T₄) and differed significantly. While there was no insect recorded in glass container (T₃) and steel container (T₅).

Almost the similar trend was observed among the treatments at 120 days after storage. At 150 days cloth bag (T₁) recorded the maximum *C. cephalonica* attack followed by mud container (T₄) and polythene cover (T₂) and differed significantly; while there was less infestation in glass container (T₃) and steel container (T₅) (Table 33).

4.3.4.2 *S. oryzae*

The sandige stored in cloth bag infested with *S. oryzae* at 120 days, recorded 1.00 insect followed by 5.75 and 10.00 insects at 150 and 180 days respectively and differed significantly; when stored in polythene cover recorded the infestation of (1.00) insect at 150 days followed by 3.00 adults, at 180 days which also differed significantly. When the produce stored in glass containers recorded 2.25 insects at 120 days followed by 5.00 and 7.00 insects at 150 and 180 days respectively and differed significantly. However, the produce stored in steel container was free from insect incidence even up to 180 days.

Among the storage containers, the produce stored in cloth bag attacked at 120 days by *S. oryzae* at 120 days while in other containers, no insect attack and differed

Table 33. Shelf life of Sandige against *C. cephalonica*

Insect species	Storage Structure	Duration (days)							Mean	
		0	30	60	90	120	150	180		
<i>C. cephalonica</i>	T₁	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	5.75 (2.49)	9.75 (3.19)	15.00 (3.93)	4.64 (1.90)	
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	5.00 (2.34)	0.85 (1.00)	
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.00 (1.56)	0.28 (0.82)	
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.25 (1.63)	4.00 (2.11)	8.00 (2.91)	11.00 (3.38)	3.60 (1.73)	
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	
	Mean	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.85 (1.06)	1.95 (1.34)	3.75 (1.74)	6.60 (2.38)		
	F- value*									
	SEM± CD@P=0.01	A			B			AB		
	0.02 0.07			0.02 0.06			0.06 0.17			

Figures in parenthesis were $x+0.5$ transformed values

T₁. Cloth bag

T₄. Mud container

T₂. Polythene cover

T₅. Steel container

T₃. Glass containe

significantly. At 150 days and 180 days also, cloth bag (T₁) recorded maximum insects followed by mud container (T₄) and differed significantly. While there was fewer insects in polythene cover (T₂); further, no insects found in glass container (T₃) and steel container (T₅) (Table 34).

Table 34. Shelf life of Sandige against *S. oryzae*

Insect species	Storage Structure	Duration (days)							Mean	
		0	30	60	90	120	150	180		
<i>S. oryzae</i>	T₁	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	5.75 (2.49)	10.00 (3.23)	2.39 (1.39)	
	T₂	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	3.00 (1.86)	0.57 (0.94)	
	T₃	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	1.00 (1.18)	0.14 (0.77)	
	T₄	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	2.25 (1.63)	5.00 (2.34)	7.00 (2.73)	2.03 (1.36)	
	T₅	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	
	Mean	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.65 (0.98)	2.35 (1.48)	4.20 (1.94)		
	F- value*									
		SEM± CD@P=0.01	A 0.09 0.27			B 0.08 0.22		AB 0.21 0.60		

Figures in parenthesis were $\times+0.5$ transformed values

T₁. Cloth bag

T₂. Polythene cover

T₃. Glass container

T₄. Mud container

T₅. Steel container

DISCUSSION

V. DISCUSSION

The results of studies on insect pests of ragi value added products, biology of *C. cephalonica* and shelf life of ragi value added product are discussed here under the light of available literature.

The present study has brought to light five insect pest species feeding on the ragi value added products (*viz.*, Hurihittu, Papad, Sandige and Chakali) belong to two orders of class insecta in different localities (ZARS Storeroom, V.C. Farm Storeroom, Mandya city, PG girl's Hostel and Hebbal Girl's Hostel). As such there has been no published information on insect pests of ragi value added products from Karnataka and elsewhere in India.

5.1 Insect pests of ragi value added products and their seasonal incidence

5.1.1 Insect pests of ragi value added products

The survey work on recording insect pests on stored grains and other products such as rice, maize, sorghum, barley, oilseeds, and pulses was conducted by several scientists in India and other countries. In the present study, five insect pests belonging to two orders of class Insecta was recorded under different store rooms at different locations at varying intensities. The present study is almost corroborated with the findings of Brar *et al.* (1987), who have recorded more than 8 insect pests on oilseeds; the present study is also corroborated with El-Kashlan *et al.* (1995) who have reported 15 insect pests infesting different stored grains such as wheat, wheat flour, barley rice and rice in Egypt. In a similar study Rostom (1993) recorded 16 species of insect pests as grainivorous on wheat, maize, wheat bran and other dust samples from Riyan and Damnam province of Saudi Arabia. Buchelos and Katopodis (1995) recorded 21 insect pests from different products.

The present study is also in agreement with the work of Sonelal and Srivastava (1985), who have recorded 3 insect pests *viz.*, *S. oryzae*, *R. dominica* and *T. granarium* infesting stored wheat. Borikar *et al.* (1977) recorded 8 insect pests on different stored grains of maize and sorghum. Similar work also reported by Bharadwaj *et al.* (1979) on stored maize. The present study is also corroborated with the findings of Pande and Das (1984), who have recorded more than 6 insect pests on stored cereals. Similar studies were also reported by Barak and Harain (1981) and Veeranki *et al.* (1999), on different stored grain products.

5.1.2 Seasonal incidence of major insect pests infesting ragi value added products

S. oryzae

In the present study *S. oryzae* infestation was higher during rainy season (June to December) and minimum during January to May. Further maximum pest incidence was recorded during November on Hurihittu. Almost the same trend was observed on Vermicelli, Papad and Sandige at all locations (Fig 1). This may be due to variation in climatic conditions such as temperature, relative humidity and rainfall received during the period of investigation at all locations. All these favoured multiplication and further the pest build up. However, there was no incidence of *S. oryzae* on chakali throughout the period of investigation indicating no preference. However, this investigation needs further studies.

The present study is almost corroborated with the findings of El- Kashlan *et al.* (1995), who have reported the higher incidence during spring and summer (July to December) on stored grain products. As such there is no published information on the incidence of *S. oryzae* on ragi value added products to discuss.

C. cephalonica

The rice moth, *C. cephalonica* was noticed throughout the year varied level of infestation at all study locations. The pest incidence was higher during December and

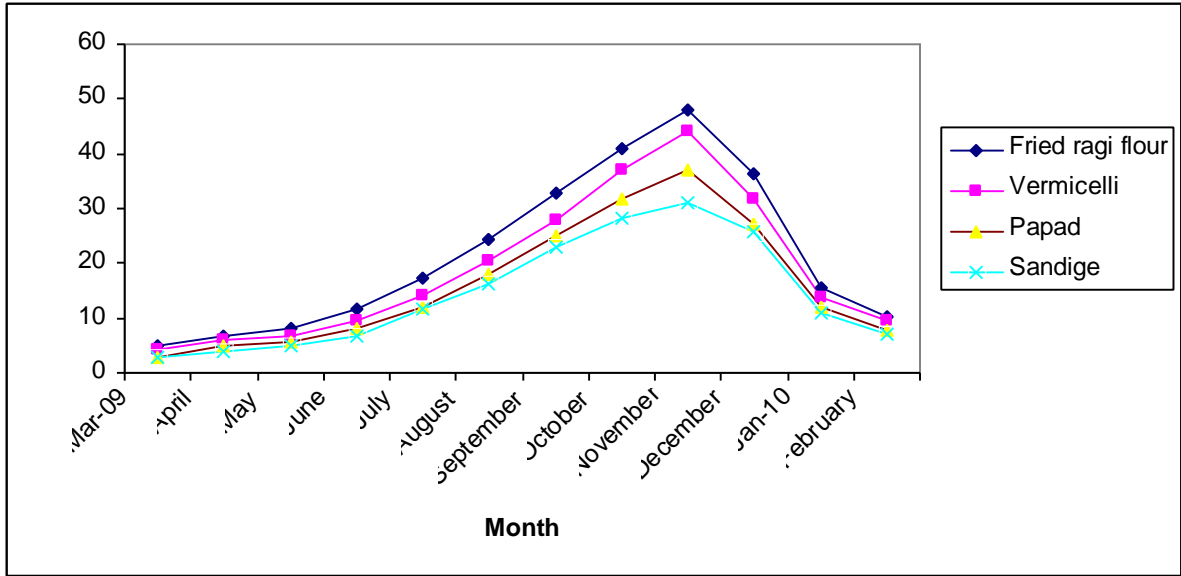


Figure 1. Seasonal incidence of *Sitophilus oryzae* on ragi value added products

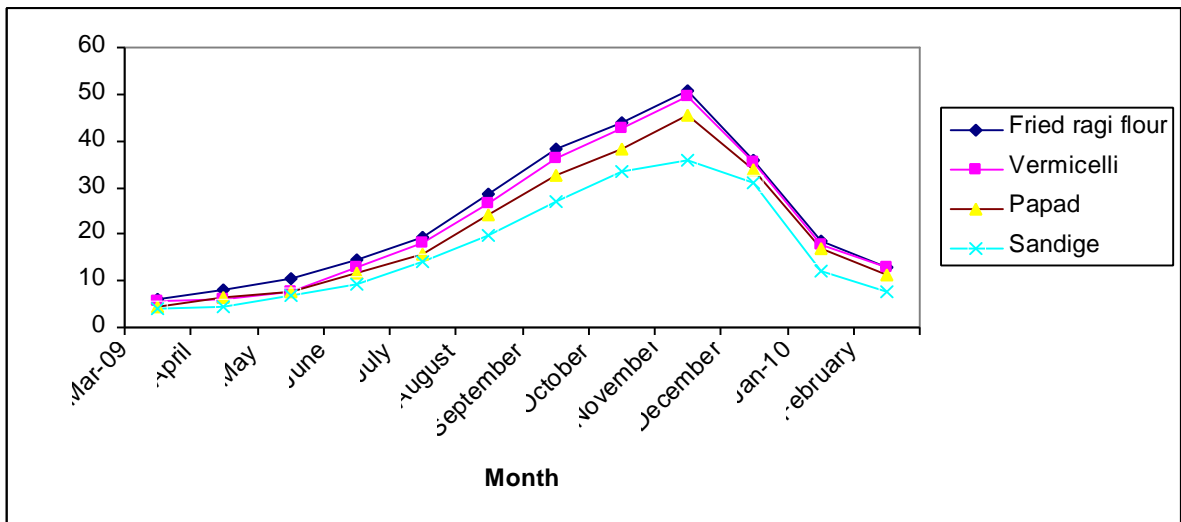


Figure 2. Seasonal incidence of *Corcyra cephalonica* on ragi value added products

lower during February to March at all locations on fried ragi flour. Almost similar trend was noticed on other products at all locations (Fig 2). There was no record of *C. cephalonica* on Chakali (muruku) indicating no preference.

The present study is almost corroborated with the report of Ayyar (1934), who reported peak activity from June to August and minimum during February on maize. Further, SeshagiriRao (1956) reported its incidence less during the periods of high temp and low relative humidity and high during low Temperature and high relative humidity as in monsoon. Similarly, Mbata (1991), reported high incidence from September to October in Nigeria. The present study also corroborated with the findings of Bandopadyaya and Ghosh (1999), who have also reported higher incidence from July - August in West Bengal. However, the present study, differ with the findings of Atwal (1976), Jalali and Singh (1992), Srivastava (1996), who have reported peak activity from March to November. This variation may be due to variation in weather conditions and geography.

C. maculatus

The pulse beetle *C. maculatus* incidence was noticed throughout the year. Incidence of the beetle was maximum during July to December and relatively less during January to June on Hurihittu (Fig 3) Almost, the same trend was observed on vermicelli at all locations. Further, the pulse beetle incidence was not noticed on other products at all locations indicating no preference.

The pest incidence was more during rainy season because of low temperature and high relative humidity favouring the pest multiplication and builds up. As such there is no published data to discuss.

T. castaneum

The lesser grain borer incidence was also higher during July to January and lower during February to June on all products at all locations (Fig 4). Further the products

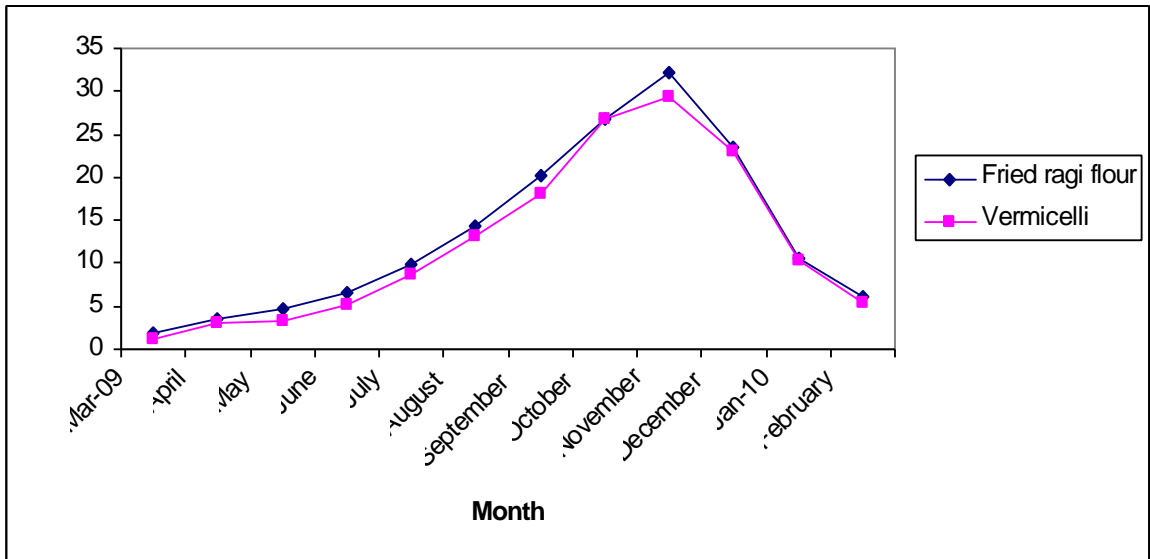


Figure 3. Seasonal incidence of *Callosobruchus maculatus* on ragi value added products

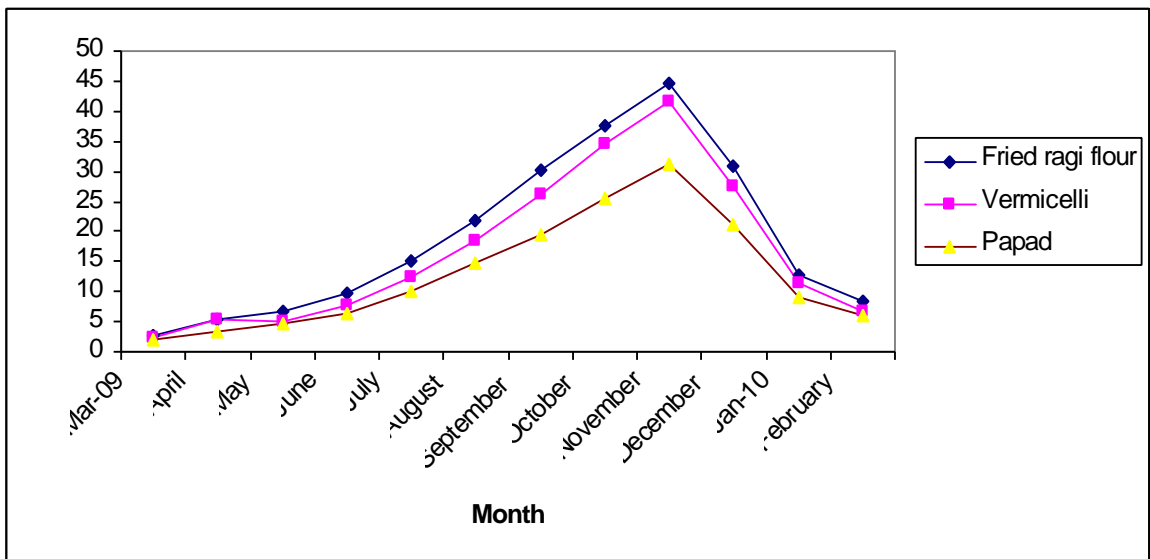


Figure 4. Seasonal incidence of *Tribolium castaneum* on ragi value added products

Chakali and Sandige were free from *T. castaneum* infestation. The present study is almost in agreement with the findings of El-Kashlan *et al.* (1995) who have reported the occurrence of *T. castaneum* on stored grains in Egypt.

L. serricorne

The incidence of cigarette beetle was varied from 1.50 to 16.12 at all study locations on Hurrihittu. The incidence of pest was maximum during July to January and minimum during February to June at all location on Hurihittu and Vermicelli (Fig 5). Further the cigarette beetle was not found on Chakali, Sandige and Papad.

There is no published information on the occurrence of this pest on ragi value products to discuss.

5.2 Biology of *C. cephalonica*

Newly laid egg was glistening, pearly whitish with irregularly sculptured surface having small divided uneven areas on the surface. Egg was pear shaped and gently rounded at one end and some what pointed at the pedicel end, which had a brownish tinge. Similar observations were made by Ayyar (1934). The present observations pertaining to egg measurement 0.50 to 0.60 mm length; mean 0.55mm and width 0.30 to 0.40mm: mean 0.35mm) are in close agreement with Ayyar (1934), who recorded egg measurements of 0.55 to 0.65mm length and 0.33 to 0.36mm width.

In the present study, prior to hatching the chorion became rather transparent through which the larva came out by making ragged hole which was bitten in the side of the egg through which the head is forced out. Ayyar (1934) observed that the first instar larva was in a curled position in egg shell.

The results relating to incubation period ranged from 4 to 7 days (mean of 4.34 ± 0.900 days) on ragi value added products was in close agreement with Prakash and

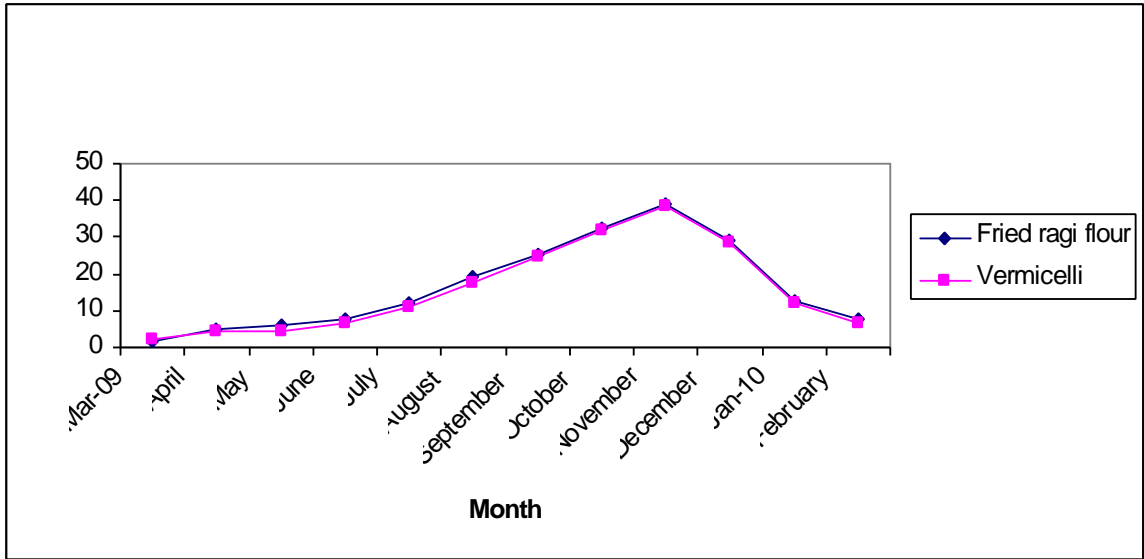


Figure 5. Seasonal incidence of *Lasioderma serricorne*. on ragi value added products

Kumar (2005), who documented 4.21 days in *Pennisetum americanum* followed by *Oryzae sativa* (5.32 days) and *Sorghum bicolor* (7.12 days); similarly, Shailaja (2008) documented 4.84 days on proso millet. Contrary to this Kamel and Hassanein (1969a) reported 3.2 days at 32⁰ C in Egypt and Carmona recorded 9 days at 20⁰ C in USA. . The differences observed in the present investigation could be due to the difference in the host used as well as the geographic locations.

Freshly emerged larva was creamy white in colour and the head capsule was yellowish white with brownish margin and the cervical shield was not very distinct but demarcated as a light yellowish area. The setae are whitish; dorsal ones are longer than the width of the body. The first instar larva was active and moving in a crawling fashion. Second instar larva had slight colour variation with pronounced thoracic shield.

The movement of the larva was restricted at this stage and in all other subsequent stages larvae were lying in curled position. The 3rd to 6th abdominal segments had prolegs and crowned with a complete circle alternated with short crochets but anal prolegs do not have complete circle which were extended in the sixth instar larva. The descriptions are of the six larval instars corroborate the findings of Ayyar (1934) who gave detailed descriptions on larval morphology.

The period occupied for larval development was 5 to 7, 8 to 9, 5 to 6, 6 to 7, 4 to 5 and 9 to 11 days with a mean of 5.70 ± 0.823 , 8.50 ± 0.527 , 5.66 ± 0.516 , 6.73 ± 0.483 , 4.33 ± 0.483 and 9.82 ± 0.918 respectively for six larval instars with a total larval period of 37-45 days at 25⁰C and 70 per cent relative humidity. These results are in contrast to that of Ayyar (1934) who reported the total larval developmental period of 38 days on ragi and maize, 42 days on wheat, 57 days on sorghum and 53 days on paddy. The variations in larval durations observed in the present investigation could be due to the variation in the host used as well as to the geographic locations.

The pupa is deep leathery brown in colour, which is enclosed in a cocoon. The cocoon is more or less elongate and thinly woven, having elliptical shape at one end

which is the provision for adult emergence. In the present study, the pupae were distinguished by size where female pupa was larger than male pupa. Similar observation also reported by Ayyar (1934).

The pupal period of 11 to 15 days with a mean of 11.94 ± 1.22 days recorded in the present study are not confirm the findings of Ayyar, 1934, Mbata (1989) who reported the mean pupal period to be 7.5, 8.3, 7.6, 8.4 and 8.5 days on groundnut, cocoa, maize, rice and cowpea at 30°C and 80 percent relative humidity in Nigeria.

Externally in adult stage males and females showed variation in size. The insect was uniformly dark grey in colour with a few dark hairlines on the body, the wing measurements recorded 14 to 23mm length in females and 14 to 18mm length in males. The sex was determined by shape of the labial palpi. The labial palpus in females was elongate and snout like projection and blunted in males, as reported by Ayyar (1934).

The present investigation has revealed the developmental period on Hurihittu ranged from 52 to 67 days with a mean of 59.35 ± 6.12 days at 25°C and 70 percent relative humidity. These results were in agreement with the studies of Ayyar (1934) who documented 57 days on sorghum and SeshagiriRao (1954) reported 47 to 57 days on broken maize. (Prakash and Kumar, 2005) stated that total developmental period was shortest on *Pennisetum americanum* (39.99 days) and longest in *Sorghum bicolor* (48.15 days) and 47.05 days on *O. sativa*; Cox *et al.* (1981) who claimed 42 days on wheat at 25°C and 70 per cent humidity in United Kingdom.

The present revelations on the negatively phototropic nature of this insect, its weak attraction to light, only attracted when exposed to strong light. The pest was nocturnal in habit and the moths took flight only when disturbed. This agrees with observations of Ayyar (1934) and SeshagiriRao (1954). The first mating took place within 12 to 24 hours after adult emergence which was also observed by Ayyar (1934) and Thomas (1961).

Copulation as reported by Ayyar (1934), normally took place at noon time in bright light. Mating Period ranged from 55 to 120 minutes (average: 85.5 ± 22.29 minutes), which varied from the findings of Thomas (1961) who reported it to be a day or two. Repeated copulation or mating was less frequent or uncommon in this pest as reported by Ayyar (1934) and Seshagiri Rao (1954).

The pre-ovipositional period (from emergence to first egg laying) was spread over 1 to 2 days with an average of 1.35 days which is close agreement with Patel and Patel (2007) and Manjunath (1993) who reported pre ovipositional period ranging from 1.18 to 1.4 and 1.69d respectively.

The ovipositional period ranged from 5 to 8 days with a mean of 6.40 ± 1.49 days which is in close agreement with Patel and Patel (2007) who reported ovipositional period ranging from 5.5 to 6.21 days on different host commodities. However, present results are slightly in contrast to the observations of Mbata (1989) (4 to 7 days). The number of eggs laid varied considerably. Similar observations were made by Ayyar (1934) and Seshagiri Rao (1954). Occasionally, the eggs were laid in groups of 3 to 4 as observed by Ayyar (1934) and Atwal (1976).

Fecundity of 250 to 430 eggs (average of 318.8 ± 85.04 eggs per female), which varied with the observation made by Ayyar (1934) who reported a fecundity of 89 to 291 eggs with an average of 206 eggs per female and Manjunath (1993) reported 358 to 620 eggs per female with an average of 467.67 eggs. Haritha *et al*, (2000) reported average fecundity of moth was higher on groundnut kernels (277 eggs) than on groundnut pods (229 eggs). The variation may be host and other weather factors.

Longevity of 8-12 days (9.88 ± 1.77 days) in unmated males, 5 to 18 days (7.43 ± 3.07 days) in mated males, 8 to 16 days (11.62 ± 3.07 days) in mated females was observed. These results agree with findings of Chensuchinug and Peng wukang (1998) but except for unmated male (mean longevity of mated female and male was 8.1 and 12.9 days respectively, of those unmated male was 10.2).

Adult females provided with 50 per cent honey solution lived 8 to 14 days with mean of 8.50 ± 1.05 days; while without food survived 6 to 13 days with mean of 8.23 ± 2.65 . Moreover the females either in the presence of food or absence lived longer than the males. The present investigation confirms the findings of Ayyar (1934) and Manjunath (1993) but disagree with that of Cotton (1941) who reported males to have a longer life.

5.2.1 Nature of damage and infestation behaviour

The newly emerged larva after hatching was very active and started crawling in search of suitable product. After choosing the product, it started feeding; the faecal pellets were used to attach the adjacent products tightly together. Like this, the larva formed a cluster of products and was found feeding inside the cluster.

Besides feeding on Hurihittu the larva pollutes products mixing with copious quantities of excreta, frass and webbing of food grains into clumps. Each larva makes 3 to 4 clumps. Pupation was inside the product cluster. Larvae feed on Hurihittu product voraciously. Nature of damage and feeding behaviour on others was similar to that on Hurihittu product.

The amount of food required by individual larva during its life cycle was 0.23 g which is different from Parameshwar and Jai Rao (1987a) who reported 0.58 g broken sorghum grain required by individual larva during its life cycle. The difference seen in present investigation could be due to difference in host used as well as geographic location.

5.2.3 Influence of different hosts of ragi value added products viz., Hurihittu, Vermicelli, Papad and Sandige on the biology of *C. cephalonica*

The incubation period on different ragi value added products, viz., Hurihittu, Vermicelli, Papad, Sandige and Chakali was 4.00 days. The shortest larval period of

38.20 days was observed on fried ragi flour followed by Vermicelli (47.20), Papad (48.90) and Sandige (49.07). The shortest pupal period of 11.92 days was observed on Hurihittu; while the longest pupal period of 12.80 days was observed on Sandige.

The longevity of male varied from 7.40 to 8.20 days while that of female from 11.60 to 12.40 days. The longevity of adult male was also minimum (7.40) on Hurihittu followed by Vermicelli (7.70), Papad (8.00) and Sandige(8.20). Similarly, the longevity of female was lower (11.60) in Hurihittu, followed by Vermicelli, Papad and Sandige. The fecundity of the moth was maximum (283.00) when reared on Hurihittu followed by Vermicelli (152.80), Papad (119.80) and Sandige (92.90).

The total developmental period (egg + larva + pupa) was recorded. The results indicated that the shortest developmental period was recorded on Hurihittu (59.30) followed by Vermicelli (64.00), Papad (68.30) and Sandige (70.32). The reasons for shorter developmental period on Hurihittu may be due to high nutritive value, easy digestibility, palatability (Fig 6).

In a similar study Kamel and Hassanein (1969a) in Egypt reported average larval duration of 46.5 days in powdered field beans followed by 58.5 days and 77 days, respectively on wheat flour and wheat bran. Further, Shazali and Smith (1986) recorded average larval period of 21.7 to 29.8 days at 25 to 35⁰ C and 60 to 80 per cent relative humidity on sorghum flour; Prakash and Kumar (2005) reported that total developmental period was shortest on *Pennisetum americanum* (39.99 days) and longest in *Sorghum bicolor* (48.15 days) and 47.05 days on *O. sativa*; while, Cox *et al.* (1981) who claimed 42 days on wheat at 25⁰C and 70 percent humidity in United Kingdom; Mbata (1989) recorded average larval periods of 29.2, 26.7, 48.1 and 47.2 days on broken maize, maize, whole and broken cocoa beans, respectively. Haritha *et al.* (2000) reported average fecundity of moth was higher on groundnut kernels (277 eggs) than on groundnut pods (229 eggs).The slight variation with respect to all parameters may be host, weather conditions and geographical conditions.

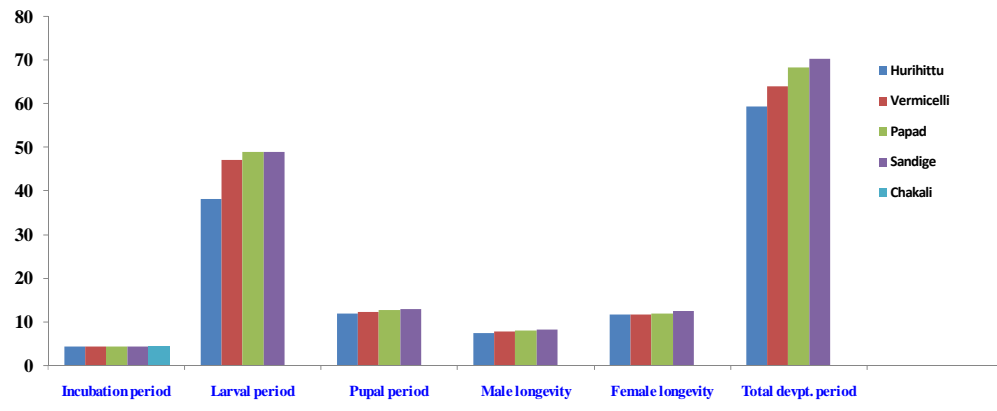


Figure 6. Comparison of different parameters *C. cephalonica*

5.3 Shelf life of ragi value added products

5.3.1 Hurihittu

C. cephalonica

Hurihittu stored in cloth bag was infested *C. cephalonica* with at 30 days and increased gradually up to 74.25 insects/sample at 180 days (Fig 7). While the same produce stored in polythene cover, free from insect infestation to 90 days and recorded the pest infestation up to 20.00 insects per sample at 180 days; later increased gradually. Similarly the Hurihittu stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container was infested at 90 days and gradually increased to 29.00 insects per sample at 180 days. While the same produce stored in steel container is free from *C. cephalonica* attack till 120 days and later recorded lower incidence at 180 days.

Among the different storage structures the produce stored in cloth bag was infested by *C. cephalonica* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to other storage structures. Further, lowest incidence was observed in steel container followed by glass container, polythene cover and mud container.

The reasons given earlier for high infestation of *C. cephalonica* to Hurihittu stored in cloth bag compared to other storage containers same holds good for *S. oryzae* with all respects; similarly, the findings of earlier workers mentioned to agree/not agree for *C. cephalonica* also holds good for *S. oryzae* also (Fig 7).

S. oryzae

Hurihittu stored in cloth bag was infested with *S. oryzae* at 30 days and gradually increased upto 65 insects/sample at 180 days. While the same produce stored in polythene cover, free from insect infestation up to 90 days and recorded the pest infestation up to 24 insects at 180 days; later, increased gradually. Similarly the Hurihittu stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 90 days and increased gradually to 29.00 insects at 180 days; while the same produce stored in steel container was free from *S. oryzae* attack till 150 days and later recorded lower incidence at 180 days.

Among the different storage structures, the produce stored in cloth bag was infested with *S. oryzae* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures such as polythene cover, glass container, mud container and steel container. Further lowest incidence was observed in steel container followed by glass container, polythene cover and mud container (Fig 8).

The highest infestation was recorded in cloth bag, may be due to the increase in moisture content and oxygen requirement of insect was abundantly met and led to rapid multiplication. The lowest infestation was recorded in steel container, this may be due to the air tightness and low moisture content and that retarded the growth and development. The findings are in close agreement with Dhaliwal *et al.* (1977), ShankarDass (1977), Agrawal *et al.* (1981), Khound and Borah (1984), Sonelal and Srivastava (1985), Singh and Yadav (1995), who have also reported that the steel container is best; further, bag storage was the worst affected storage system.

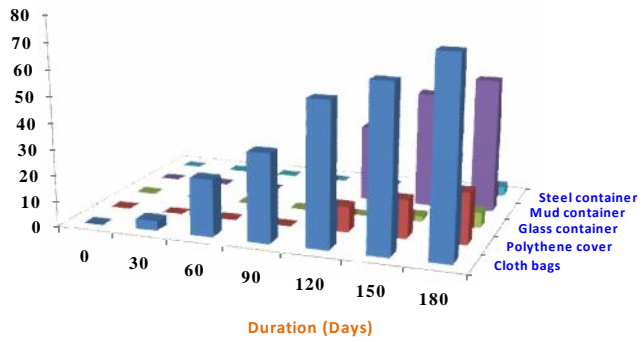


Figure 7. Shelf-life of Hurihittu against *C. cephalonica* on different storage structures

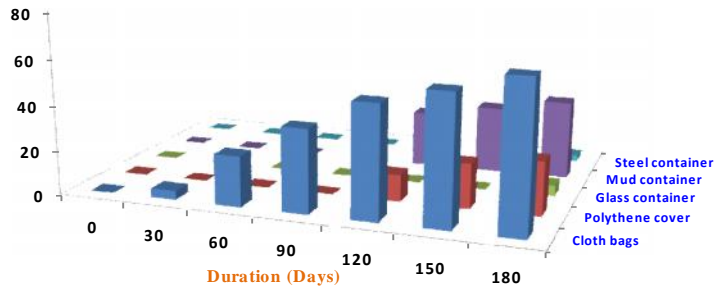


Figure 8. Shelf-life of Hurihittu against *S. oryzae* on different storage structures

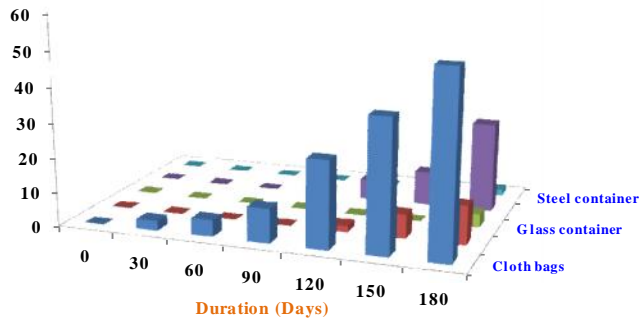


Figure 9. Shelf-life of Hurihittu against *T. castaneum* on different storage structures

The present study slightly; differ with Borikar *et al.* (1977), who have observed that the grains stored in kangi were heavily infested with rice weevil, lesser grain borer, pulse beetle and red flour beetle than bagged commodities. However, the infestation of grain moth, flat grain beetle and rice moth was more in bagged produce.

T. castaneum

Hurihittu stored in cloth bag infested with *T. castaneum* at 30 days and gradually increased to 52.00 insects/sample at 180 days (Fig 9). While the same produce stored in polythene cover, free from insect infestation up to 90 days and recorded the pest infestation to 11.25 insects/sample at 180 days; later gradually increased. Similarly the Hurrihittu is stored in glass container is free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 90 days and gradually increased to 29.00 insects / sample at 180 days. While the same produce stored in steel container is free from *T. castaneum* attack till 150 days and later recorded lower incidence at 180 days.

Among the different storage structures the produce stored in cloth bag infested by *T. castaneum* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structure. Further lowest incidence was observed in steel containers followed by glass container, polythene cover and mud container (Fig 9).

The reasons given earlier for high infestation of *C. cephalonica* and *S. oryzae* to Hurihittu stored in cloth bag compared to other storage containers same holds good for *T. castaneum* with all respects; similarly, the findings of earlier workers mentioned to agree/not agree for *C. cephalonica* and *S.oryzae* also same holds good for *T. castaneum* also.

5.3.2 Vermicelli

C. cephalonica

Vermicelli stored in cloth bag was infested with *C. cephalonica* at 30 days and gradually increased up to 52.00 insects/sample at 180 days (Fig 10). While the same produce stored in polythene recorded free from insect infestation till 90 days and recorded the pest infestation up to 23.85 at 180 days; later gradually increased. Similarly the Vermicelli was stored in glass container was free from insect infestation till 120 days and infestation was recorded at 150 days. While the same stored in mud container infested at 90 days and gradually increased to 29.00 insects at 180 days. Further the produce stored in steel container was free from *C. cephalonica* attack till 150 days and later recorded lower incidence at 180 days (Fig 10).

Among the different storage structures the produce stored in cloth bag was infested by *C. cephalonica* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150, and 180 days after storage compared to other storage structures. Further lowest incidence was observed in steel containers followed by glass container, polythene cover and mud container.

S. oryzae

Vermicelli stored in cloth bag was infested with *S. oryzae* at 60 days and gradually increased up to 43.00 insects/sample at 180 days (Fig 11). While the same produce stored in polythene cover, free from insect infestation up to 90 days and recorded the pest infestation up to 17.00 insects at 180 days; later gradually increased. Similarly the vermicelli stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 120 days and gradually increased to 23.00 insects /sample at 180 days. While the same

produce stored in steel container was free from *S. oryzae* attack till 150 days and later recorded lower incidence at 180 days (Fig 11).

Among the different storage structures the produce stored in cloth bag was infested by *S. oryzae* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures. Further lowest incidence was observed in steel container followed by glass container, polythene cover and mud container.

T. castaneum

Vermicelli stored in cloth bag was infested with *T. castaneum* at 120 days and gradually increased to 22.00 insects/sample at 180 days (Fig 12). While the same produce stored in polythene cover was free from insect infestation up to 120 days and recorded the pest infestation up to 7.75 insects / sample at 180 days; later gradually increased. Similarly the Vermicelli stored in glass container is free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 120 days and gradually increased to 15.00 insects/ sample at 180 days. While the same produce stored in steel container is free from *T. castaneum* attack till 150 days and later recorded lower incidence at 180 days (Fig 12).

Among the different storage structures the produce stored in cloth bag was infested by *T. castaneum* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures. Further lowest incidence was observed in steel containers followed by glass container, polythene cover and mud container.

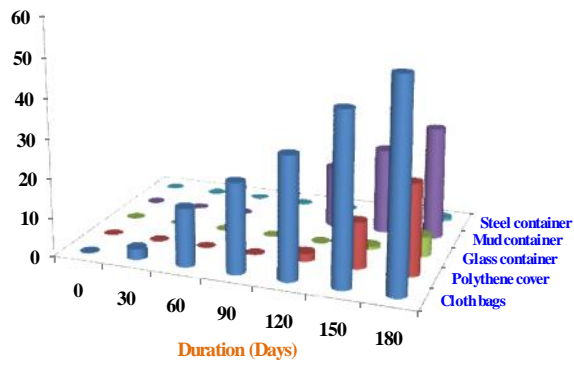


Figure 10. Shelf-life of 'Vermicelli' against *C. cephalonica* on different storage structures

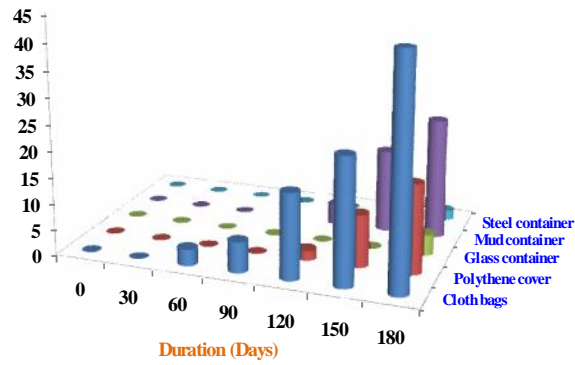


Figure 11. Shelf-life of 'Vermicelli' against *S. oryzae* on different storage structures

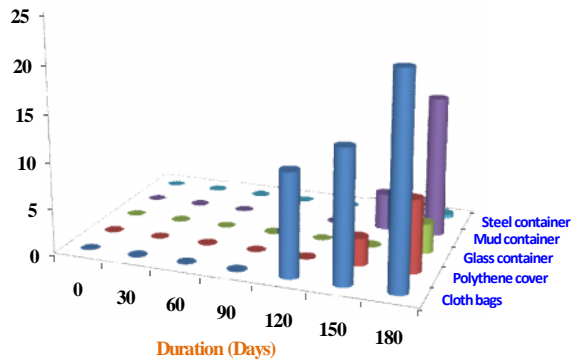


Figure 12. Shelf-life of 'Vermicelli' against *T. castaneum* on different storage structures

The reasons given earlier for high infestation of *C. cephalonica*, *S. oryzae* and *T. castaneum* to vermicelli stored in cloth bag compared to other storage containers same holds good with all respects; similarly, the findings of earlier workers mentioned to agree/not agree for *C. cephalonica*, *S.oryzae* and *T. castaneum* also same holds good.

5.3.3 Shelf life of papad

C. cephalonica

Papad stored in cloth bag was infested with *C. cephalonica* at 30 days and gradually increased up to 40.00 insects/sample at 180 days (Fig 13). While the same produce stored in polythene cover free from insect infestation up to 90 days and recorded the pest infestation up to 12.00 insects at 180 days; later gradually increased. Similarly the papad stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container was infested at 90 days and gradually increased to 18.00 insects/ sample at 180 days. While the same produce stored in steel container was free from *C. cephalonica* attack till 120 days and later recorded lower incidence at 180 days (Fig 13).

Among the different storage structures the produce stored in cloth bag infestation by *C. cephalonica* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures. Further lowest incidence was observed in steel container followed by glass container, polythene cover and mud container.

S. oryzae

Papad stored in cloth bag was infested with *S. oryzae* at 60 days and gradually increased up to 30.00insects/sample at 180 days (Fig 14). While the same produce stored

in polythene cover was free from insect infestation up to 90 days and recorded the pest infestation up to 13.00 insects /sample at 180 days; later gradually increased. Similarly the Papad stored in glass container was free from insect infestation till 120 days and infestation was recorded at 150 days. While the same stored in mud container was infested at 60 days and gradually increased to 22.00 insects /sample at 180 days. While the same produce stored in steel container was free from *S. oryzae* attack till 150 days and later recorded lower incidence at 180 days (Fig 14).

Among the different storage structures the produce stored in cloth bag was infested by *S. oryzae* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structures at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to other storage structure. Further lowest incidence was observed in steel container followed by glass container, polythene cover and mud container.

T. castaneum

Papad stored in cloth bag was infested *T. castaneum* with at 60 days and gradually increased upto 18.00 insects/sample at 180 days. While the same produce stored in polythene was free from insect infestation up to 90 days and recorded the pest infestation upto 6.00 insects at 180 days. Later gradually increased. Similarly the Papad was stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 60 days and gradually increased to 10.00 insects at 180 days. While the same produce stored in steel was free from *T. castaneum* attack till 150 days and later recorded lower incidence at 180 days (Fig 15).

Among the different storage structure the produce stored in cloth bag was infested by *T. castaneum* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly

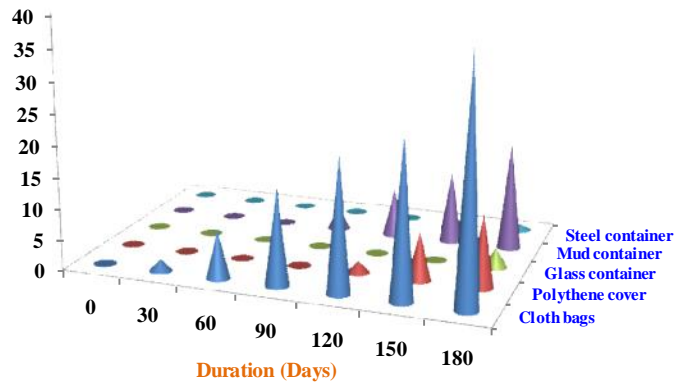


Figure 13. Shelf-life of 'Papad' against *C. cephalonica* on different storage structure

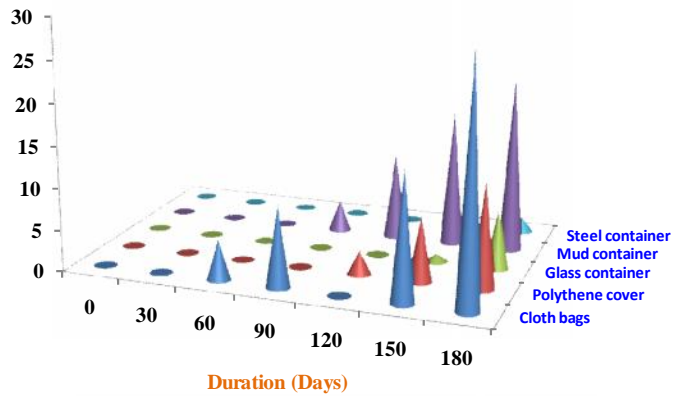


Figure 14. Shelf-life of 'Papad' against *S. oryzae* on different storage structure

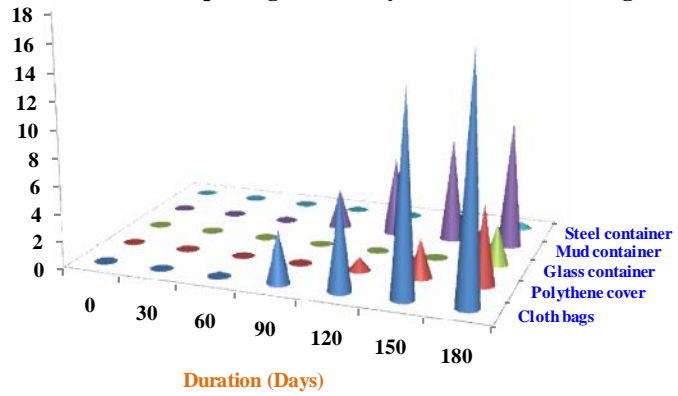


Figure 15. Shelf-life of 'Papad' against *T. castaneum* on different storage structures

the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compare to the other storage structure polythene cover, glass container, mud container and steel container. Further lowest incidence was observed in steel containers followed by glass container, polythene cover and mud container.

The reasons given earlier for high infestation of *C. cephalonica*, *S. oryzae* and *T. castaneum* to Papad stored in cloth bag compared to other storage containers same holds good with all respects; similarly, the findings of earlier workers supported in some cases and not corroborated for *C. cephalonica*, *S.oryzae* and *T. castaneum* also same holds good the same reasons for this also.

5.3.4 Shelf life of Sandige

C. cephalonica

Sandige stored in cloth bag was infested with *C. cephalonica* at 60 days and gradually increased up to 15.00 insects/sample at 180 days (Fig 16). While the same produce stored in polythene cover, free from insect infestation up to 120 days and recorded the pest infestation up to 5.00 insects at 180 days; later gradually increased. Similarly the Sandige stored in glass container was free from insect infestation till 150 days; later, infestation was recorded at 180 days. While the same stored in mud container infested at 60 days and gradually increased to 11.00 insects at 180 days. While the same produce stored in steel was free from *C. cephalonica* attack even up to 180 days (Fig 16).

Among the different storage structures the produce stored in cloth bag infested by *C.cephalonica* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures. Further lowest incidence was observed in steel container followed by glass container, polythene cover and mud container.

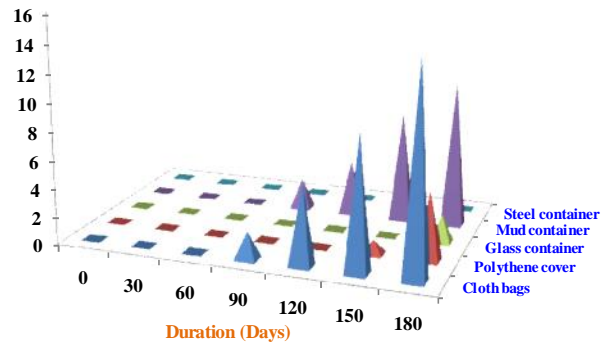


Figure 16. Shelf-life of 'Sandige' against *C. Cephalinica* on different storage structures

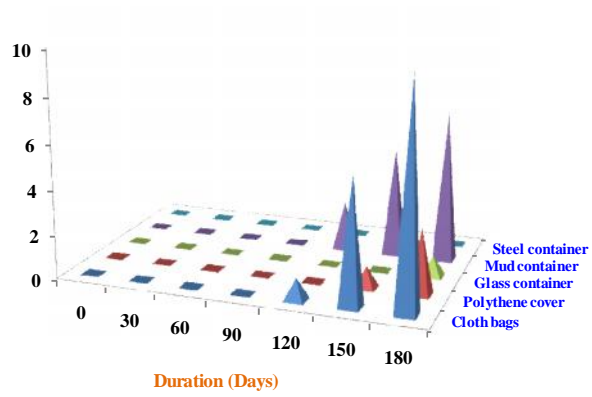


Figure 17. Shelf-life of 'Sandige' against *S. oryzae* on different storage structures

S. oryzae

Sandige stored in cloth bag was infested with *S. oryzae* at 90 days and gradually increased up to 10.00 insects/sample at 180 days (Fig 17). While the same produce stored in polythene cover free from insect infestation up to 120 days and recorded the pest infestation up to 3.00 insects at 180 days. Similarly the Sandige stored in glass container was free from insect infestation till 150 days and infestation was recorded at 180 days. While the same stored in mud container infested at 90 days and gradually increased to 7.00 insects at 180 days. While the same produce stored in steel was free from *S. oryzae* attack even up to at 180 days (Fig 17).

Among the different storage structures the produce stored in cloth bag was infested by *S. oryzae* at 30 days, while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structure at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compare to the other storage structures. Further lowest incidence was observed in steel containers followed by glass container, polythene cover and mud container.

The reasons given earlier for high infestation of *C. cephalonica*, *S. oryzae* and *T. castaneum* to Hurihittu, Vermicelli and Papad stored in cloth bag compared to other storage containers same holds good with all respects; similarly, the findings of earlier workers mentioned to agree/not agree for *C. cephalonica*, *S.oryzae* and *T. castaneum* also same holds good.

SUMMARY

VI. SUMMARY

The results of studies on insect pests of ragi value added products and their incidence, biology of *Corcyra cephalonica* Stainton on Hurihittu and shelf life of ragi value added products are summarized below.

The present study has brought to light five species of insect pests *viz.*, *Sitophilus oryzae*, *Corcyra cephalonica*, *Tribolium castaneum*, *Callosobruchus maculatus* and *Lasioderma serricorne* feeding on ragi value added products at different localities namely ZARS storeroom, V. C. Farm storeroom, Mandya city, Hebbal girl' s hostel and PG girl' s hostel.

The rice weevil, *S. oryzae* was found infesting Hurihittu in varying intensities throughout the year at different localities. Both adults and grubs are the damaging stages. The incidence was higher during June-December and relatively less during February-May. Almost the same trend was noticed on Vermicelli, Papad and Sandige at all locations. There was no incidence of weevil on Chakali (Muruku) throughout the year.

The rice moth, *C. cephalonica* larvae initially fed on the flour for a while, later formed web on the flour, excretal pellets and made galleries. The pest incidence was higher during June to December and relatively less from February to May at all locations on Hurihittu. Almost the same trend was noticed on other products *viz.*, Vermicelli, Papad and Sandige at all locations. Further there was no incidence of *C. cephalonica* on Chakali (Muruku).

The pulse beetle, *C. maculatus*, incidence was noticed only on Hurihittu and Vermicelli. The pest incidence was maximum from June to December and relatively less during January to May. Same trend was observed on Vermicelli.

Rust red flour beetle, *T. castaneum* grubs construct tunnels and feed as they move through flour and adults can feed on the products that are already damaged by other

insects. The incidence level was higher during July to January, relatively low during February to June. Almost similar observations were recorded on Vermicelli and Papad at all locations. The products like Sandige and Chakali (Muruku) were free from *T. castaneum* infestation.

The cigarette beetle, *Lasioderma serricorne*, adults and grubs fed freely on all products without webbing. However few grubs mixed the flour. The incidence was maximum during July to January and minimum during February to June at all locations on Hurihittu. Almost the similar observations were recorded on Vermicelli at all locations. Further, there was no incidence on Papad, Sandige and Chakali (Muruku).

Detailed investigations on the biology of *C. cephalonica* was made only on Hurihittu; while total developmental period (egg+ larva+ pupa) of *C. cephalonica* was recorded on other ragi value added products viz., Vermicelli, Papad, Sandige and Chakali (Muruku). Besides, biology, nature of damage, quantity of food requirement and other behavioural studies were also made.

Adult moths were small uniformly dark grey in colour with few dark hair lines and were active towards noon. The phenomenon of mating was described in detail. The whole process took 55 to 120 minutes. The pre-ovipositional period was 1 to 2 days. Presence of the host was not essential to induce oviposition. The eggs were generally laid loosely in the petridish or in some cases sticking to the inner surface of the containers. The eggs were occasionally laid in clusters or in groups of 3 to 4. The fecundity ranged from 254 to 392 eggs, oviposition period lasted 5 to 8 days irrespective of presence or absence of food. The incubation period of *C. cephalonica* on Hurihittu was 4.34 days. Newly hatched larva was creamy white in colour and passed through six instars on Hurihittu. The mean duration of six instars was 5.70, 8.50, 5.66, 6.73, 4.33 and 9.82 days respectively. The last instar larva was quite inactive occupying major portion of the tunnel inside the product cluster made by the larva. Total larval period was 37 to 45 days. The pupa was deep leathery brown coloured found in the grain cluster which was enclosed in white silken cocoon. The pupal period was 11.94 days. The adult longevity

was 7.43 and 11.62 days in mated males and females respectively. *C. cephalonica* took 52 to 67 days to complete development on Hurihittu.

Studies were made on the influence of ragi value added products viz., Hurihittu, Vermicelli, Papad, Sandige and Chakali (Muruku) on the biology of *C. cephalonica* (total developmental period); The larvae fed on surface of the products and caused formation of clumps, which contained intact broken products, excuviae, silken cocoon, dust and detritus. The larval duration was 38.20, 47.20, 48.90 and 49.07 days while pupal duration was 11.92, 12.30, 12.60 and 12.80 days on Hurihittu, Vermicelli, Papad and Sandige respectively. The study showed shortest total developmental period of 38.20 days on Hurihittu and longest of 49.07 days on Sandige. The longevity of both adult male and female was shortest on Hurihittu (7.40 & 11.60 days) and longest (8.20&12.40days) on Sandige. The fecundity was maximum (283.00) on Hurihittu and minimum (92.90) on Sandige. The shortest total developmental period (egg+ larva+ pupa) was on Hurihittu and longest on Sandige.

Hurihittu stored in cloth bag infested with *C. cephalonica* at 30 days and gradually increased to 74.25 insects /sample at 180 days .While the same produce stored in polythene cover, free from insect infestation at 90 days and recorded the pest infestation of 20 insects at 180 days; later, increased gradually. Similarly the Hurihittu stored in glass container was free from insect infestation till 120 days and lower infestation was recorded at 180 days. While the same stored in mud container was infested at 90 days and increased gradually to 52.00 insects at 180 days; while the same produce stored in steel container was free from *C. cephalonica* attack till 120 days and later recorded lower incidence at 150 and 180 days.

Among the different storage structures, the produce stored in cloth bag was infested with *C. cephalonica* at 30 days while in other containers no insect attack was noticed. Almost similar trend was observed among the storage structures at 60 days after storage. Similarly the produce stored in cloth bag recorded the maximum infestation at 90, 120, 150 and 180 days after storage compared to the other storage structures such as

polythene cover, glass container, mud container and steel container. Over all, the Hurihittu stored in cloth bag were less infested at 30 days and increased gradually at 60, 90, 120, 150 and 180 days by *C cephalonica*. Almost similar findings were recorded in Vermicelli, Papad and Sandige with respect to duration and storage containers in case of other pests viz., *S. oryzae*, and *T. castaneum*.

REFERENCES

VII. REFERENCES

- ALLOTEY, J. AND AZALEKOR, W., 2000, Some aspects of the biology and control using botanicals of the rice moth, *Corcyra cephalonica* Stainton on some pulses. *J. Stored Prod. Res.*, **36**(3): 235-243.
- AGRAWAL, R. K., SINGH, K. N. AND SRIVASTAVA, P. K., 1981, Studies on the assessment of storage of losses in wheat due to stored grain insect pest in U.P. *Bull. Grain Tech.*, **19**: 198-200.
- *ANONYMOUS., 2004, *Corcyra cephalonica* Stainton [Distribution map]. CAB International, Nosworthy Way, Wallingford, Oxfordshire, OX10 8DE, UK. Distribution Maps of Plant Pests. pp 656.
- ARBOGAST, R.T AND MULLEN, M. A., 1988, Insect succession in stored corn ecosystem in South East Georgia. *Annals of Entomological Society of America*, **81**: 899-912.
- ATWAL, A. S., 1976, Agricultural pests of India and South East Asia. pp. 392-394.
- *AVILESPACHECO, R. J. AND ACEVEDO, R., 1983, Damage caused by the moth *Corcyra cephalonica* Stainton to stored rice. *Agricultura.*, **14**: 45-49.
- AYERTEY, J. N. AND IBITOYE, J. O., 1987, Infestation of maize and sorghum seeds by *Sitophilus*, *Rhizopertha* and *Sitotroga* in three contiguous climatic zone in Nigeria. *Insect Science and Application*, **8**: 981-987.
- AYYAR, P. N. K., 1934, A very destructive pest of stored products in South India, *Corcyra cephalonica* Stainton (Pyralidae: Lepidoptera). *Bull. Ent. Res.*, **25**(2): 155-169.

- BACK, E. A. AND COTTON, R. T., 1926, The cadelle. *Dept. Bull. U. S. Dept. Agric.*, **1428**: 41-43.
- BANDYOPADHYAY, B. AND GHOSH, M. R., 1999, Loss of food grains by insect pests during storage in three agro climatic zones of West Bengal. *Environment and Ecology*, **17**(3): 701-705.
- BARAK, A. V. AND HAREIN, P. K., 1981, Insect infestation of farm stored shelled corn and wheat in Minnesota. *J. Econ. Entomol.*, **74**: 197-202.
- BARTELS, D., 2002, *Corcyra cephalonica* Stainton- an overlooked pest. *Bulletin. OILB/SROP.*, **25**(3): 33-40.
- BASDEN, J. F., 1950, A method of distinguishing the larval stages of *Agriotes sputator* (L.) (Coleoptera: Elateridae). *Bull. Ent. Res.*, **41**: 395-413.
- BEVERIDGE, W. W. O., 1913, A preliminary report on the temperature reached in army biscuits during baking, especially with reference to the destruction of the imported flour moth, *Ephestia kuhniella* Zeller. *J. Roy. Army Med. Corps.*, **20**(6): 615-634.
- BHARADWAJ, A. K., SINGH, S. AND SRIVASTAVA, P. K., 1979, Storage losses in maize due to insect pests damage in Punjab. *Bull. Grain Technol.*, **17**: 22-25.
- BORIKAR, P. S., PAWAR, V. M. AND SURYAWANSHI, D. S., 1977, Survey of insect pests of stored grains in Marthawada region. *Bull. Grain Technol.*, **15**: 153-155.
- BRAR, H. S., CHAHAL, B. S. AND RAMZAN, M., 1987, Insect pests of stored oilseeds in Punjab and Chandigarh. *J. Res. Punjab agric. Univ.*, **24**(3): 437-440.

- BUCHELOS. C. T. AND KATOPODIS, 1995, A survey of beetles in storerooms containing barley and maize for animal feed on the Islands of Lefkars, Greece. *J. Stored Product Res.*, **31**: 253-258.
- *CARMONA, M. M., 1958, A entomofauna dos produtos armazenados *Corcyra cephalonica* Stainton. *Estudos, Ensaios Documentos, Ministerio do Ultrama, Lisboa*, **55**: 17-19.
- CHAMP, B. R. AND DYTE, C. E., 1977, FAO global survey of pesticide susceptibility of stored grain pests. *Pl. Prot. Bull.*, **22**(2): 49-67.
- CHATTERJI, S., 1961, Effect of initial moisture content of different food materials on development and sex-ratio in *Corcyra cephalonica* Stainton. *Curr. Sci.*, **30**(2): 104-105.
- CHENSUCHIUNG, S. AND WUKANG, P., 1998, Emergence and longevity of rice moth *C.cephalonica* (Stainton) (Lepidoptera: Pyralidae). *Chinese J. Entomol.*, **18**(2): 135-140.
- CHITTENDEN, F. H., 1919, The Rice Moth. U. S. Dept. agric. (USDA) *Bull no.783*.
- COTTON, R. T., 1941, Insect pests of stored grain products. *Burg. Publ. Co. Minneapolis, minor*. U.S.A., pp. 9-11.
- COX, P. D., CRAWFORD, L. A., GEISTRUD, G., BELL, C. H. AND BOWLEY, C. R., 1981, The influence of temperature and humidity on the life cycle of *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). *Bull. Ent. Res.*, **71**: 171-181.
- DARLING, H. S., 1952, Insects and grain storage in Sudan. *Sudan Notes Rec.*, **32**: 131-149.

DEVERAJ URS, K. C. AND MUKHERJEE, P. B., 1966, Effect of oilseed food on the biology of *Tribolium castaneum* Herbst. *Trogoderma granarium* Everts. *Corcyra cephalonica* Stainton and their susceptibility to pyrethroids. *Indian J. Ent.*, **28**(2): 234-240.

*DHALIWAL, G. S., 1977. Incidence of storage pest in rural areas. *Indian. J. Ent.*, **39**: 114-116.

EL-KASHLAN, I. H., EGLAL HELAL, MADEHA A. B. D., EL-HAMID AND ABDELLATIF, M. A., 1995, Insect pests associated with stored grains in Alexandria Governorate, A. R. E. *J. King Saud Univ.*, **7**: 123-127.

ETMAN, A. A. M., EL-SAYED, F. M. A., EESA, N. M. AND MOURSY, L. E., 1988, Laboratory studies on the development, survival, mating behaviour and reproductive capacity of the rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). *J. Appl. Ent.*, **196**(3): 232-240.

FREEMAN, J. A., 1948, Preservation of grains in storage. *FAO. Agricultural Studies*, **2**: 15-24.

FREEMAN, J. A., 1976, Problems of stored products entomology in Britain arising out of the import of tropical products. *Ann. Appl. Biol.*, **84**: 120-124.

GAINES, J. C. AND CAMPBELL, F. L., 1935, Dayr's rule as related to the number of instars of the corn ear worm *Heliothis obsoleta* Fab. Collected in the field. *Ann. Entom. Soc. Amer.*, **28**: 446-461.

GOOD, N., 1933, Biology of the flour beetles, *Tribolium castaneum* Duy. and *Tribolium ferrugineum* Fab. *J. Agric. Res.*, **46**: 327-334.

- HARITHA, V., VIJAYALAKSHMI, K. AND MURTHY, M. M. K., 2000, Biology of rice moth, *Corcyra cephalonica* Stainton on groundnut pods and kernels under controlled condition. *J. Appl. Zool. Res.*, **11**(2/3): 135-136.
- HERFORD, G. V. B., 1933, The more important pests of cocoa, tobacco and dried fruit. *Bull. Imp. Inst.*, **31**: 39-55.
- HODGES, R. J., 1979, A review of the biology and control of the rice moth *Corcyra cephalonica* Stainton (Lepidoptera: Galleriinae). *Rep. Trop. Prod. Inst.*, **125**: 20.
- HOWE, R. W., 1965, Losses caused by insects and mites in stored food and feeding stuffs. *Nutr. Abst. Rev.*, **35**(2): 285-303.
- HUGAR, P. AND JAIRAO, K., 1991, Rate of multiplication of rice moth, *Corcyra cephalonica* Stainton. *Agric. Sci. Digest. Karnal.*, **11**(4): 195-198.
- IVBIJARO, M. F., 1978, Deterioration of commercial maize (*Zea mays* L.) by insects and fungus. Department of Agricultural extension. *Indian University, Nigeria*. 309-312.
- JACOB, S., VILASINI, T. N., SUJA, G. AND JOHN, S., 2002, Loss assessment in groundnut test entries due to storage pests. *Insect Environ.*, **8**(2): 93-94.
- JALALI, S. K. AND SINGH, S. P., 1992, Effect of infestation of sorghum grains by different dosages of *Corcyra cephalonica* Stainton eggs on adult emergence patterns. *Entomon*, **17**(1/2): 117-119.

- KAMEL, A. H. AND HASSANEIN, M. H., 1967, Biological studies on *Corcyra cephalonica* Stainton (Lepidoptera: Galleriinae). *Bull. Soc. Ent. Egypte.*, **51**: 175-196.
- *KAMEL, A. H. AND HASSANEIN, M. H., 1969a, Biological studies on *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). *Bull. de la Societe Entomologique d' Egypte.*, **51**: 175-196.
- *KHOUND, J. N. AND BORAH, D. C., 1984, Evaluation of 3 indoors bins for storage of wheat in Assam. *Bull. Grain Tech.*, **20**: 62-65.
- KRISHNAMURTHY, B. AND RAO, S. D., 1945, Alternate media for large scale rearing of the rice moth (*Corcyra cephalonica* Stainton) in the work of mass production of the egg parasite, *Trichogramma minutum* Riley. *Curr. Sci.*, **14**(10): 81-82.
- KULAKARNI, S. M., 1969, Observations on some effects of temperature and isolation on fecundity of female *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). *Indian J. Ent.*, **30**(4): 286-288.
- KUMAR, P. AND KUMAR, S., 2002, Evaluation of different rearing media for *Corcyra cephalonica* Stainton. *J. Biol Control.*, **16**(2): 117-120.
- KUMAR, S. A., SHENMAR, M. AND BRAR, K. S., 2002, Development of *Corcyra cephalonica* Stainton on different foods. *J. Res. Punjab Agric. Uni.*, **39**(2): 218-220.
- MAHATHI, V., 2002, Ecology and management of stored grain pests of maize. Ph. D. Thesis, Acharya. N. G., Ranga Agricultural University, Hyderabad.

- MANJUNATH, T. M., 1993, Qualitative and quantitative analysis of techniques leading to economic mass production of *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). Ph. D. thesis, *Univ. Agri. Sci*, Bangalore.
- MBATA, G. N., 1989, Studies on some aspects of the biology of *Corcyra cephalonica* Stainton (Lepidoptera: Galleriidae). *J. Stored Prod. Res.*, **25**(4): 181-186.
- *MBATA, G. N., 1991, A survey of the incidence and abundance of insect pests of stored groundnuts in the Ibadan area of Nigeria. *Nigerian J. Ent.*, **11**(1/2): 75-89.
- MEDINA, C. P. AND CADAPAN, E. P., 1982, Mass rearing of *Corcyra cephalonica* Stainton and *Trichogramma spp.* *Phillipine Entomologist*, **5**(2): 181-198.
- MEYRICK, E., 1895, A hand book of British Lepidoptera, pp. 384.
- MEYRICK, E., 1928, Report of insect infestation of dried fruits. E. M. B. No.12.
- MILES, H. W., 1931, Growth in the larvae of Tenthredinidae. *J. Exp. Biol.*, **8**: 355-364.
- MUNRO. J. W. AND THOMPSON, W. S., 1929, Report on insect infestation of cocoa. *Biol. Abst.*, **5**: No. 28793.
- NEELAKANTHAN, P., 1972, Post harvest technology of food crops, problems and perspective in post harvest technology of cereals and pulses. In: Proceedings of symposium held at New Delhi, (Eds.) Pingale, S. V., Austin, A. and Nair, M.T.R. pp. 102.
- NOYES, W. M., 1930, Moth pests in cocoa and confectionary. *Bull. Ent. Res.*, **21**: 77-121.

- OSMAN, N., 1984, Assessment of damage by the rice moth *Corcyra cephalonica* Stainton on different grains at four levels of moisture content. *Proc. 7th ASEAN Tech. Seminar on Grain Post Harvest Technol.*, Kuala Lumpur. pp. 99-106.
- PAJNI, H. R. AND GILL, K. M., 1974, Effect of light on the pests of stored products. *Bull. Grain Tech.*, **12**(2): 151-153.
- PANDE, Y. D. AND DAS. K., 1984, Relative abundance and extent of losses caused insects to stored grains in Tripura. *Bull. Grain. Tech.*, **22**: 209-214.
- PARAMESHWAR, H. AND JAI RAO, K., 1987a, Food consumption by the larvae of rice moth, *Corcyra cephalonica* Stainton. *Agric. Sci. Digest.*, **7**(4): 196-198.
- PARKER, J. R., 1930, Some effects of temperature and moisture upon *Melanoplus mexicanus* Sauss and *Camula pellucida* Scudder (Orthoptera). *Bull. Mont. Agric. Exp. Stn.*, **223**: 132.
- PATEL, R. A AND PATEL, B. R., 2007, Comparative biology of rice moth, *Corcyra cephalonica* Stainton. *J. Plant Prot. Environ.*, **4**(1): 14-19.
- POTTER, C., 1935, The biology and distribution of *Rhizopertha dominica* Fab. *Trans. R. Ent. Soc. London(A)*., **83**: 449-574.
- PRAKASH, R. A. AND KUMAR, P. S., 2005, Biology of *Corcyra cephalonica* Stainton on important cereals and millets. *Insect Environ.*, **11**(2): 86-87.
- PREVETT, P. F., 1963, *Stathmopoda auriferella* (Wlk.) (Lepidoptera: Heliodinidae) infesting sorghum on the head in Northern Nigeria. *Bull. Ent. Res.*, **54**: 5-8.

- PRUTHI, H. S. AND SINGH, M., 1950, Pests of stored grain their control. Issued by I.C.A.R., pp.1-88.
- PURANDARAM, T., 1976, Indian standards help in national grain saving. *Bull. Grain. Technol.*, **14**(2): 146-153.
- RAGONOT, E. L., 1885, "Revision of the British species of Phycitidae and Galleriidae", *Ent. Mo. Mag.*, **22**: 17-32.
- RAI, M., 2000, Productivity grain focus, Survey of Indian Agriculture. *In: The Hindu*, pp. 53-55.
- RAJ, D., 1976, Studies on the optimum potential and economics of mass rearing of *Trichogramma brasiliensis* Ashmead. *Entomological Newsletter.*, **6**(2): 23-24.
- RAMAKRISHNAAYYAR, T. V., 1919, Some insects recently noted as injurious in South India. *Proc. Third Ent. Meeting. Pusa.*, **1**: 323.
- RAMASWAMI, S., SARMA, P. S. AND SRINIVASAYA, M., 1942, Studies in insect Nutrition: assay of quality in crops. *Curr. Sci.*, **11**(2): 53-54.
- RAMESH, L. AND VAIDYA, D. N. AND MEHTA, P. K., 2000, Relative abundance and extent of losses in unhusked rice due to stored grain insect pests in Kangra district of Himachal Pradesh. *Pest Management Econ. Zools.*, **8**(2): 129-132.
- RAMESH, L. AND VAIDYA, D. N., 2001, Weight loss in maize grains due to insect infestation in different storage structures. *Insect Environ.*, **7**(1): 37-39.
- RAY, R., 1994, Life tables and intrinsic rate of increase of *Corcyra cephalonica* Stainton on maize. *Environ. Ecol.*, **12**(1): 202-204.

- RAY, R., SHI, N. AND PATNAIK, H. P., 1990, The life table and intrinsic rate of increase of *Corcyra cephalonica* Stainton on jowar. *Orissa J. Agric. Res.*, **3**(1): 22-26.
- RICHARDS, O. W. AND HERFORD, G. V. B., 1930, Insects found associated with cocoa spices and dried fruits in London warehouses. *Ann. Appl. Biol.*, **17**: 367-395.
- RICHARDS, O. W. AND THOMPSON, W. S., 1932, A contribution to the study of the genera *Ephestia*, Gn. And *Plodia*, Gn. (Lepidoptera: Phycitidae) with notes on parasites of the larvae. *Trans. Ent. Soc. London.*, **80**: 169-250.
- ROHWER, S. A. AND MIDDLETON, W., 1922, North American sawflies of the subfamily Cladinae, *Proc. U. S. Nat. Mus.*, **60**: 1-46.
- ROSTOM. M. F. Z., 1993, Survey of some granivorous and non-granivorous insects and mites of stores in Saudi Arabia. *J. Stored. Prod. Res.*, **29**(1): 27-31.
- *RUSSEL, V. A., SCHULTEN, G. G. M. AND ROORDA, F. A., 1980, Laboratory observations on the development of the rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) on millet and sorghum at 28⁰ C and different relative humidities, *Jeitschrift Angewandte Entomologii*. Royal Tropical Institute, Department of Agricultural Research, Maxritskade, Amsterdam, Netherlands. pp. 64.

- SATTERTHWAIT, A. F., 1933, Larval instars and feeding of the black cutworm *Agrotis epsilon* Roh. *J. Agric. Res.*, **46**: 517-530.
- SESHAGIRIRAO, D., 1954, Notes on rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). *Indian J. Ent.*, **15**: 95-144.
- SESHAGIRIRAO, D., 1956, Notes on rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Galleriinae). *Rev. Appl. Ent.*, **44**: 13-14.
- *SHANKARDASS., 1977, Survey of insect pest in rural storage structures of Haryana and estimation of quantitative and qualitative losses caused by them. Ph. D. thesis,, *Hissar Agricultural University*, Hisar.
- SHAILAJA 2008, Biology and infestation behaviour of *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) on Proso millet (*Panicum miliaceum* L.). M.sc.Thesis, *Univ. agric. sci.*, Bangalore.
- SHAZALI, M. E. H. AND SMITH, R. H., 1986, Life history studies of internally feeding pests of stored sorghum: *Sitotroga cerealella* (Ol.) and *Sitophilus oryzae* (L.). *J. Stored Prod. Res.*, **21**: 171-178.
- SINGH, D. AND YADAV, T. D., 1995, Studies on the incidence of insect pests, practices and losses in stored wheat in Haryana. *Indian J. Ent.*, **57**(2): 107-115.
- *SINHA, R. N., 1975, Climate and the infestation of stored cereals by insects. *Proc. 1st Int. Wkg Conf. Stored Prod. Ent.*, Savannah, Ga, pp. 117-141.
- SONELAL, AND SRIVASTAVA, B. P., 1985, Insect pests of stored wheat in Madhya Pradesh (India). *J. Ent. Res.*, **9**(2): 141-148.
- SRIVASTAVA, K. P., 1996, Applied Entomology. *Kalyni Publ.*, **2**: 271.

- STAINTON, H. T., 1866, Description of new species of the family Galleriidae. *Ent. Mo. Mag.*, **2**: 172-173.
- STONE, M. W., 1941, Life history of the sugar beet wireworm in Southern California. *Tech. Bull. U.S. Dept. Agric.*, **7**: 44-87.
- *SUCHIUNG, C. AND WUKANG, P., 1998, Emergence and longevity of the rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Galleriinae). *Chinese J. Ent.*, **18**(2): 135-140.
- SWAMY, B. G. L. AND SRINIVASAYA, M., 1942, Studies in insect nutrition; Symptomology of Avitaminosis in *Corcyra cephalonica*, Stainton: A histological study. *Curr. Sci.*, **11**(2): 147.
- TEOTIA, T. P. S. AND SINGH, Y., 1975, Studies on growth of populations of *Corcyra cephalonica* Stainton. *Indian J. Ent.*, **37**: 277-285.
- THOMAS, P. M., 1961, Control of rice moth in warehouses. No. CWC/Tech-1A/WH/60-61.
- UBEROI, N. K., 1960, Nutritional requirements of the larvae of the rice moth *Corcyra cephalonica* Stainton- Studies on feeding response to various natural foods. *Proc. Indian Acad. Sci. B.*, **53**: 234-247.
- USMAN, S., 1968, The number and the relation between measurements of successive larval instars of the rice moth *Corcyra cephalonica* Stainton (Lepidoptera: Galleriidae). *Mysore J. Agric. Sci.*, **2**(3): 181-192.
- VEERANKI, S. AND REDDY, K. D., 1999, Insect pests scenario in stored maize in Karimnagar and Nizamabad districts of Andhra Pradesh. *J. Res. ANGRAU.*, **27**(4): 15-17.

WALOFF, N., 1948, Development of *Ephesia elutella* (Hubner) (Lepidoptera: Phycitidae) on some natural foods. *Bull. Ent. Res.*, **39**: 117-130.

WALTER, E. M., 1971, Sorptive dusts for pest control. *Ann. Rev. Ent.*, **16**: 123-156.

WWW.indiastat.com

*Originals not seen