# ERGONOMIC EVALUATION OF CONVENTIONAL AND IMPROVED METHODS OF *AONLA* PRICKING


**BY**

**Arpana Rai**

**[2010HS161M]**


***Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University in the partial fulfillment of the requirements for the degree of:***

**MASTER OF SCIENCE**

**IN**

**FAMILY RESOURCE MANAGEMENT**


**I.C.COLLEGE OF HOME SCIENCE**
**CCS HARYANA AGRICULTURAL UNIVERSITY**
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## CERTIFICATE – I

This is to certify that this thesis entitled **“Ergonomic Evaluation of Conventional and Improved Methods of *Aonla* Pricking”** submitted for the degree of **Master of Science**, in the subject of **“Family Resource Management”** to the CCS Haryana Agriculture University, is a bonafide research work carried out by **Arpana Rai** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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## CERTIFICATE – II

This is to certify that this thesis entitled, **"Ergonomic Evaluation of Conventional and Improved Methods of *Aonla* Pricking"** submitted by **Arpana Rai** to the CCS Haryana Agricultural University in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of **"Family Resource Management"** has been approved by the Student's Advisory Committee after an oral examination of the same.

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*Gratitude cannot be seen or expressed, it can only be felt deep in heart and is beyond description. Although 'thanks' are poor expression of debt of gratitude one feels, yet there is no better way to express it.*

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**Dated : May, 2012** **(Arpana Rai)**

**Place : Hisar**

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AICRP on PHT | : | All India Coordinated Research Project on Post Harvest Technology |
| BMI | : | Body Mass Index |
| BPDS | : | Body Part Discomfort Score |
| CCR | : | Cardiac Cost of Recovery |
| CCW | : | Cardiac Cost of Work |
| CTS | : | Carpel Tunnel Syndrome |
| EATs | : | Ergonomic Assessment Tools |
| EER | : | Energy Expenditure Rate |
| FPO | : | Fruit Products Order |
| HR | : | Heart Rate |
| ILO | : | International Labour Organization |
| LBP | : | Lower Back Pain |
| LEP | : | Lower Extremity Pain |
| MSDs | : | Musculoskeletal Disorders |
| NMQ | : | Nordic Musculoskeletal Questionnaire |
| OSH | : | Occupational Safety and Health |
| OSHA | | Occupational Safety and Health Administration |
| OWAS | : | Ovako Working Posture Analysis System |
| PCW | : | Physiological Cost of Work |
| PFI | : | Physical Fitness Index |
| RPE scale | : | Rating of Perceived Exertion Scale |
| RSM | : | Response Surface Methodology |
| RULA | : | Rapid Upper Limb Assessment |
| SMEs | : | Small- Medium Enterprises |
| TCCW | : | Total Cardiac Cost of Work |
| VAD scale | : | Visual Analogue Discomfort Scale |
| WISE | : | Work Improvement in Small Enterprise |
| WRMSDs | : | Work Related Musculoskeletal Disorders |

# CHAPTER–I

## INTRODUCTION

India is one of the major food producing countries in the world. India's fruit production capacity of 42 million metric tons (M.T.) ranks it first in the world. Presently, the processing of fruits and vegetables is estimated to be around 2.2% of the total production in the country (India country overview, World Bank, 2008). A huge number of entrepreneurs in food processing industry especially in fruit and vegetable processing segment are small in terms of their production and operations and are largely concentrated in the unorganized segment *i.e.* in household and small-scale sector, having low capacities of up to 250 tons per annum. According to Ministry of Food Processing Industries, this low capacity is attributed to poor infrastructure and lack of matching post harvest technology.

The fruit and vegetable processing industry has been termed as 'sun-rise industry' for India. Fruit and vegetable processing in India is almost divided between organized and unorganized sectors with the unorganized sector holding 52 percent of the share. These small-medium enterprises (SMEs) representing unorganized sector in India are playing a vital role to stimulate economic development through income generation. The small-medium processing sector especially fruit and vegetable processing sector has been traditionally viewed as the major source of employment generation for women workers because of low skill requirement of this sector. While products like juices and pulp concentrates are largely manufactured by the organized sector, the unorganized sector foothold is in the traditional area of processed items like preserves, pickles, sauces and squashes.

*Aonla* or Indian Gooseberry, (*Emblica officinalis* Gaertn) is one of the most important non-traditional and underutilized fruit crop indigenous to Indian sub-continent. *Aonla* belongs to the family Euphorbiaceae and to genus Phyllanthus and grows widely along the hillsides and sub-mountanious areas of northern India. It is small sized, minor subtropical fruit and is not consumed raw or fresh as it is acidic and astringent, therefore, not popular as table fruit. India ranks 1$^{st}$ in area and production of *aonla* and *aonla* is second highest among all the cultivated fruits in India. The mostly grown varieties are *banarasi*, *desi*, *chakaiya* etc., out of which *chakaiya* is the most important variety for commercial purpose. Owing to its hardy nature, suitability to various waste lands, high productivity/unit area (15-20 tons/ha), nutritive and therapeutic value (fruit is richest source of ascorbic acid, is cooling, diuretic and laxative), *aonla* is becoming more and more commercially important with every passing year. Status of post harvest technology of *aonla* in India shows that *aonla* has a growing popularity for alternate medicines, health foods and herbal products. It shows great potential for processing into various value added products which can have great demand in national as well as international market (Goyal *et al.,* 2008). A number of processed products *like preserve, squash, sauce, toffee, jam, jelly, pickle, chutney, supari, churan powder, barfi* and *laddoo* are prepared from *aonla* fruit to improve their acceptability and exploit nutritional qualities.

*Aonla* has been in use for preserve since ages in India. The *aonla* preserve *(murabba*) is one of the specialties of the Indian fruit-preservation industries selling hundreds of tons of preserve every year. Preserve is made from fully mature *aonla* fruit by pricking them followed by cooking in heavy sugar syrup. Till date, the equipment used and methods employed for pricking and preserve making are manual and traditional and thus, making the pricking task tiresome, time consuming and further cannot maintain quality of the end product. Women are vital and productive workers in preserve making industries and are engaged in almost all the steps of preserve making from washing of procured *aonla* fruits to bottling of end product. However, during whole process of preserve preparation, pricking task has been identified as the most monotonous job and involves maximum risk factor for the workers.

Traditionally, *aonla* fruits are pricked with hand tools which are made up of wooden or stainless steel needles for the preparation of *murabba*. The pricking operation is done on individual fruit by hand which is tiresome and time consuming. Minor accidents are also reported during pricking task. Moreover, the shelf life of the prepared product is less and the quality is not up to the mark. To overcome all these constraints, researchers are paying due attention towards processing aspects of *aonla* fruits. This requires an urgent need to design matching processing technology such as pricking machine and an appropriate methodology. Hence, an effort has been done by the All India Coordinated Research Project on Post Harvest Technology (AICRP on PHT), Hisar in College of Agricultural Engineering and Technology and they have developed a hand operated *aonla* pricking machine. Its capacity is about 15 to 20 kg/hour as compared to 2 to 3 kg per hour by manual method of pricking (Anonymous, 2009).

Technology is the development and application of tools, machines, materials and processes that help to solve human problems. Implementation of technology at the work places has contributed to economic growth and social progress as well as a reduction in many sources of occupational accidents, injuries and stresses. However, traditionally an implementation of new technology is technology centered, often failing to consider the implications on the personnel involved. The result is a sub optimal work system, not only in terms of productivity but also in terms of the physical and psychological well-being of workers (Nadin *et al.,* 2001). Consideration of ergonomics in the choice and utilization of the technology can help to create a good fit between technology, user and the operating environment (Shahnavaz, 2000). To be on the safer part every technology (machine) whether large or small must undergo an ergonomic assessment to avoid man-machine conflict in the work place which in turn will enhance work efficiency and productivity.

Ergonomics (also known as human engineering, human factors or human ergology) is the scientific study of the interaction between man and their working environment. The term environment includes the tools and materials, the method of work, ambient conditions and physical environment in which work is carried out and also the organizational factors. It is concerned with optimum design of equipment, workstations and work environment giving utmost consideration to human anatomical, physiological and psychological capabilities and limitations. The objective of ergonomics is to enhance the effectiveness and efficiency with which work is carried out and to maintain and promote worker's health, safety and satisfaction. In order to assess the fit between a person and his/her work, ergonomists have to consider many factors like the job being done and the demands on the worker, the equipment used (its size, shape and how appropriate it is for the task) and the physical environment (temperature, humidity, lighting, noise etc).

A strong relationship exists between the comfort of the worker and their productivity. The design specifications of the workplace especially the workstation in relation to worker's anthropometry, physical characteristics and job requirements have significant impact on their productivity, physical and mental well being. The workstation should be designed in such a way that workers are able to perform their jobs effectively. In addition to fatigue and the resulting deteriorated worker's performance, an awkward workplace design can result in development of occupational injuries to the workers. Workstations are typically designed either for seated or standing work and are determined by the nature of job performed at the station. Prolonged sitting, standing or squatting has been associated with fatigue and development of work related musculoskeletal disorders (WRMSDs). An alternating sit-stand work posture provides opportunity to reduce this impact and alter the amount of load experienced by body parts throughout the day. Alternation between two postures allows for increased rest intervals of specific body parts and reduced potential for the adverse impact of risk factors commonly associated with MSD development.

Every worker spends at least 8 hours a day in the workplace. Therefore, work environment should be safe and healthy. Occupational safety and health (OSH) is concerned with safety and health of workers in relation to work and the working environment. OSH at work in SMEs present a particular challenge as the majority of workforce is employed in SMEs and resources to protect and promote health of this workforce are much lesser. As a result of the hazards and lack of attention given to safety and health, work related accidents and MSDs are very common. The Occupational Safety and Health Administration (OSHA) objective of assuring as far as possible every man and woman a safe and healthy work environment could be achieved only when efforts are directed towards identifying occupational health hazards of workers. Accordingly, suitable and effective mitigating measures are to be developed and suggested to either minimize or eliminate the extent of such hazards. The implementation of WISE (Work Improvement in Small Enterprise) is thought to lead to concrete workplace improvements in these SMEs. WISE looks at the multiple aspects of workstation and productivity enhancement under local conditions (Kogi, 1985).

Therefore, in light of all these considerations/factors, the research was carried out focusing on the following objectives:

1. To examine the existing working conditions, processing tools and techniques of *aonla* pricking units
2. To conduct ergonomic evaluation of conventional and improved methods of *aonla* pricking
3. To study user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared

**Scope of the study**

Preserve making is one of the oldest cottage industries in our country employing a huge number of women workers in pricking operation. The supreme purpose of combining ergonomics with food processing units is to reduce the occupational workload on women workers by devising appropriate tools, equipment and advanced technologies for them. Several observational studies of SMEs suggest that workplace conditions, work environment and working tools and techniques were not satisfactory. Keeping these factors in consideration, this research focuses on conducting ergonomic evaluation of *murabba* making SMEs with special emphasis on the *aonla* pricking task and introducing a hand operated *aonla* pricking machine compared with conventional tools and further suitable ergonomic interventions. The study also proposes to design an appropriate workstation coupled with the best working conditions and then to plan out suitable modifications for these SMEs using WISE methodology. A search in the literature reveals that no such research has been carried out in the country related to *aonla* pricking operation, so this study will prove to be a boon for preserve making cottage industries and the workers involved in these industries.

**Limitations**

1. Due to limited time, the study could not be conducted on large scale and has been restricted to limited sample size and limited number of parameters.
2. Lesser duration of time for experiment over which workers were requested to work in each of the test procedure.

## CHAPTER–II

## REVIEW OF LITERATURE

A brief resume of past literature and researches relevant to the present study have been incorporated in this chapter. The pertinent literature related to various aspects dealt in this study has been presented under the following subheads:

2.1 Ergonomic evaluation and occupational health hazards

2.2 Workstation design and application of RSM

2.3. Ergonomic interventions in work activities

2.4. Effect on shelf life and economic benefits of using improved technology

### 2.1. Ergonomic evaluation and occupational health hazards

**Ergonomic evaluation of different activities**

Chauhan and Saha (2004) determined the acceptable limits of physiological workload for Indian women based on the relationship between energy expenditure (EE) and relative load (RL), assuming that Indian women can sustain physical activity for long duration with a RL 35% without physiological strain and undue fatigue. The acceptable limits of heart rate were worked out to be 110 beats.min$^{-1}$, 95 beats.min$^{-1}$ and 100 beats.min$^{-1}$ respectively for different age groups (21-30, 31-40, 41-50 yr) and the corresponding values of energy expenditure to be 10 kJ.min$^{-1}$, 9.6 kJ.min$^{-1}$and 10.5 kJ.min$^{-1}$ respectively. The difference, though not significant, could be attributed to influence of age, body build and level of physical fitness ($VO_2$ max), all of which modify physiological workload.

Gite *et al.* (2007) conducted ergonomic evaluation of hand operated paddy winnower on 12 women subjects in standing posture. The mean heart rate (HR), energy expenditure rate (EER), average output and winnowing efficiency of women workers during operation was found to be 112 beats.min$^{-1}$ and 10.7 kJ.min$^{-1}$, 242 kg grain per hr and 88.36 percent respectively. The equipment developed was found to be suitable for the women worker as the heart rate, work pulse value and energy expenditure rate were within the acceptable levels.

Dilbagi and Gandhi (2008) evaluated the performance of improved sickle over conventional sickle in terms of reduced drudgery and output. Experiment was conducted using four sickles comprising one conventional sickle (S0) and three improved sickles viz., S1, S2 and S3. Average working heart rate and energy expenditure rate was found minimum for S2 sickle and use of S2 sickle resulted into minimum grip fatigue after the activity. Output was found maximum with S2 sickle. Use of improved sickle reduced physiological workload as well as biomechanical stress thereby, decreased the drudgery of women workers in harvesting operation.

Kwatra *et al.* (2010) conducted an ergonomic study to compare paddy threshing activity by farm women using two methods viz. manual beating of paddy on wooden platform and by using manually operated paddy thresher. The mean HR for manual beating of paddy was found to be 154.5 beats.min$^{-1}$, whereas it was 122.5 beats.min$^{-1}$ with manually operated paddy thresher. A significant reduction in heart rate of 20.71 percent was observed by improved method. The energy expenditure rate (EER) was found to be 17.6 kJ.min$^{-1}$ for manual beating whereas with the use of paddy thresher, the EER was 12.8 kJ.min$^{-1}$ The total cardiac cost of work (TCCW) and physiological cost of work (PCW) reduced by 60.28 percent with the use of paddy thresher.

Kaur and Sharma (2010) conducted ergonomic evaluation of vegetable plucking activity with traditional (ordinary knife) and improved tool (ring cutter). Ergonomic assessment of both the method showed that by using ring cutter physiological and muscular stress of workers in terms of heart rate, energy expenditure rate, physiological cost of work and grip fatigue were reduced as compared to traditional method. Thus, new tool *i.e.* ring cutter was found to be beneficial to improve work efficiency of farm women.

**Effect on environmental factors on various activities**

Grandjean (1980) reported that for visual comfort and to meet the visual demands a suitable level of illumination, a balance of surface luminance's avoidance of glare and temporal uniformity of lighting are essential. Orientation of the building has important function to provide good natural ventilation and daylight.

Sen (1982) emphasized the usefulness of correct layout of the working area with respect to the position of windows, fans, workstations for different operations, storage etc so that the efficient movements of personnel and quicker flow of materials and products could be achieved.

**Occupational health hazards**

Prolonged standing has been associated with discomfort in the feet, legs and lower back. Conversely, prolonged sitting has been associated with a high incidence of back complaints, increased spinal muscular activity & intra disc pressure, discomfort in the lower extremities (Grandjean, 1978).

Haslegrave (1994) pointed out that good posture is important to the comfort of all people at work. A poor posture become hazard to safety and health in two main situations: in task which are static in nature and involve maintaining posture for relatively long periods and in tasks which involve the exertion of force. In the first situation, the postural load on muscles and joints can lead to muscular fatigue, pain and in long term to cumulative physiological change and injury.

A study conducted by Gangopadhyay and Bandopadhayaya (1999) in Bengali community of Calcutta revealed that there were symptoms of pain in different parts of musculoskeletal system after completion of kitchen work. It was concluded from the study that posture and mode of work had a great effect on the development of musculoskeletal disorders.

Banerjee and Gangopadhayay (2003) conducted a study to find out the prevalence of repetitive strain injuries in upper extremities among the hand loom weavers and to identify the risk factors leading to its development. Fifty male handloom weavers were randomly selected from the population. A questionnaire method including Borg's scale assessment of pain, checklist analysis of the work and time motion studies for analysis the repetitiveness/non repetitiveness of the job were implemented. The time motion analysis demonstrated that weaving occupied over 50 percent of the work cycle for majority of the subject thus could be regarded as repetitive job. Statistical analysis revealed a highly significant correlation between the intensity of pain feeling and the repetitiveness of one hand. These results suggested that highly repetitive works for a long time could increase the intensity of pain felt and lead to repetitive strain injuries.

Murali *et al.* (2004) conducted an investigation to assess the angle of postural deviation of body of farm women while performing the selected farm activities using traditional methods and improved tools and its relation with heart rate and perceived exertion. Findings revealed that there was slight variation in the angle of body bend at cervical and lumbar region of women while performing the selected activities using traditional methods and improved tools. However, the correlation between angle of body bend, heart rate and perceived exertion was non-significant for most of the activities.

Gupta *et al.* (2004) revealed that 92 percent of the farm women were comfortable using agricultural hand tools (sickle and weeding hoe) while few were uncomfortable. The reasons for uncomfortability were material of tool, weight of tool and the way of handling tool. The farm women reported frequent pain in back, neck, palm, legs, shoulders, cuts and wounds in palm. After the completion of day's work on farm, majority of the women reported pain in middle part of palm while some of them had pain at the tip of fingers or upper part of palm. Majority of the farm women perceived the reason for pain in palm was due to the way of handling the tool and design of the agricultural hand tool while others perceived the pain due to material of the tool.

Kumar *et al.* (2006) reported that hand tools constitute a significant number (58 %) of farm injuries, involving a high number of female farm workers (65 %). Hand tools accounted for 332 (58 %) and 54 (19 %) of total agricultural injuries. Analysis of farm hand tool injuries indicated different mechanism of injuries viz. slippages of tool from hand, improper handle diameter and length of handle and improper clearance for hand in handles were the major causes of hand tool injuries. Handles angularities resulted in wrist deviation causing musculoskeletal problems. Productivity is impaired to the tune of 24,000 days per hundred thousand populations because of injuries caused by hand tools on farms.

Parimalam *et al*. (2006) conducted a study to identify the health hazards of the workers involved in basket making. The study revealed that basket making involves different postures to be adopted by the workers, as a result of which majority of them have several musculoskeletal problems. Poor posture for a long time increases the postural load and causes musculoskeletal disorders. Several quantification techniques such as physical examination, body part discomfort mapping and workers responses have been used to assess the musculoskeletal problems of women bamboo workers. The findings of the study revealed that low back pain was the major problem (99 %), followed by upper arm (98 %) and shoulder pain (93 %). Analysis of the environmental parameters and the tools used by these workers also revealed the need for redesigning of work space and tools of these workers.

Sriwarno *et al*. (2006) conducted a study on Indonesians who commonly perform activities on the floor that require squatting postures. It has been identified that adopting squatting postures without any proper support would gradually cause postural stress. The study examined the influence of different squatting heights to the body kinematics and subjective discomfort rating. The subjects adopted a squatting posture at no-stool condition and at the stool height of 10, 15, and 20 cm. The task was to simulate the work close to the ground level with the hip joint deeply flexed. It was suggested that normal weight subjects sit comfortably at 15 cm stool height. These findings imply that the use of stool is able to decrease discomfort level in comparison to the no-stool or fully squatting posture.

Sriwarno *et al.* (2007) continued the same research on squatting posture to study the influence of different lower seat heights on the muscular stress. Squatting on a stool (SS) was examined in comparison with fully squatting (FS). The subjects performed forward movement under four squatting height conditions which were FS and SS at 10 cm, 15 cm and 20 cm seat height. The results demonstrated that the change from FS to SS primarily affected the segmental angular flexions and muscular activities in the upper and lower limbs. The findings of the study suggested that the use of a lower seat stool of a proper height seems to a sub-optimal solution considering the change of muscular load associated with discomfort in squatting posture. Therefore, regarding ground level jobs, a change in working posture from fully squatting to squatting on a stool has proven to reduce the muscular load.

Bhattacharya and Chakarbarti (2010) reported high prevalence of musculoskeletal disorder among tea leaf pluckers. Shoulders, back, neck and fingers were the most affected organs. Musculoskeletal disorders were mostly related to the work habit *i.e.* awkward posture, repetitiveness and duration. Hence, urgent need was felt to design a plucking device to lower down the possibilities of MSDs among workers.

Maulik *et al*. (2010) conducted a study to analyze working pattern, work posture and the workstation design of the medical laboratory and the prevalence of work related musculoskeletal disorders among the medical laboratory technicians. Working posture was mainly static. The analysis of Nordic musculoskeletal questionnaire revealed that 45 percent of the technicians were experiencing pain in lower back followed by knees and neck. Prevalence of pain by Quick exposure checklist shows that neck was the most commonly affected body part. Followed by wrist, back and shoulder. The Rapid upper limb assessment scores were also high indicating that further implementation and investigation are required soon. There was mismatch between workstation dimensions and anthropometry of workers which has caused unnatural posture, stress and resultant pain.

**2.2. Workstation design and application of RSM**

Nerhood and Thompson (1994) examined six sit-stand workstations used by keyboard operators who had been given detailed instructions in how to use and adjust their workstation heights and chairs. Measures of production levels, absenteeism and injuries (as well as a survey of discomfort) measures were compared before and after the introduction of workstation. There was a large (62%) decrease in reported discomfort, and more than 50 percent reduction in injuries.

Paul (1995) conducted study on a group of 12 employees doing intensive computer work in enclosed offices at non-adjustable workstations. It was found that when they moved to sit-stand workstations average standing for 2 hours per day, subjects reported feeling more "energetic" and "less tired" by the end of the day.

Dahalan *et al.* (2002) stated that improper design of workstation may create risks to the worker's body system due to: localized fatigue that can cause pain and discomfort to the muscles of the back, neck and shoulders; and the joints of the knees, ankles, hips, shoulders, and elbows. General fatigue that results in reduced physical ability to perform a task. It also can reduce the concentration level of employees; overexertion to the musculoskeletal system; injuries to the employee such as slipped disc, tendonitis, sprained back, and others.

Roelofs and Straker (2002) conducted a study on discomfort and preferences of 30 full-time bank tellers who worked at a standing height work surface while sitting on a high chair, then standing, and then alternating between sitting and standing. The mode in which the least reported discomfort arose and which was regarded as the preferred posture by 70 percent of subjects was alternation between sitting and standing.

Hedge (2004) reported a direct relationship between adjustable-height work surfaces and musculoskeletal discomfort among keyboard workers. Highlighting the results of a study of the use of height-adjustable work surfaces in two different companies, in which a total of 33 keyboard-based employees worked at fixed-height work surfaces and then at height-adjustable work surfaces for periods of between four and six weeks. The results of study before and four to six weeks after use of the height-adjustable work surfaces showed significant decreases in the severity of reported musculoskeletal discomfort for most upper body regions. Workers also expressed a strong preference for using work surfaces which were easily height-adjustable.

Shikdar and Hadhrami (2005) conducted a study to investigate the effects on operator performance and satisfaction in an ergonomically designed workstation for performing a repetitive industrial assembly task. Special features of the ergonomically designed assembly workstation were an adjustable and adequate worktable, an adjustable and ergonomically designed chair, ergonomically designed hand tools and a systematic layout of the workstation components. Experiments were conducted in a company with industrial workers using existing and newly developed workstations. Operator performance on the ergonomically designed workstation was 27 percent higher compared to the existing non-ergonomically designed workstation. Worker satisfaction score was also improved by 41 percent in the ergonomically designed workstation condition. The new workstation for a repetitive assembly task had highly significant positive effect on worker performance and satisfaction.

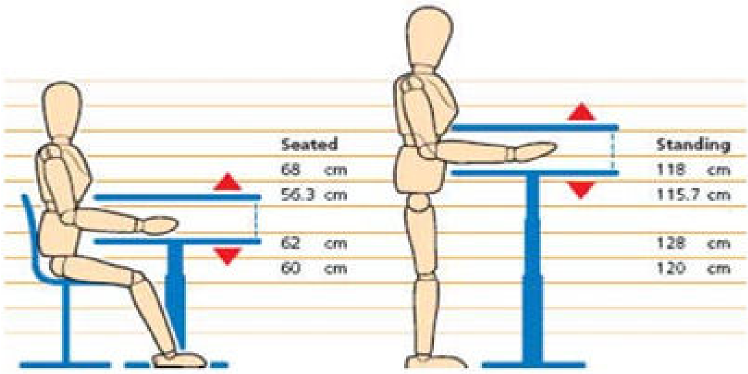
Lee *et al.* (2005) conducted an experiment to study the effect of working station height on upper extremity fatigue. Ten subjects were recruited and 9 task patterns, which were the combinations of 3 working heights and 3 parts location levels, were designed and performed in the experiment. It was found that the number of subjects with fatigue became larger with the increase of working height. The muscular stress of subjects might be reduced when parts location levels were the same or below the working heights. It was suggested that working height should be designed with the elbow level or lower and the parts location levels should not exceed the working height while a repetitive task of upper limbs was performed at worksites.

Darpanjot and Oberoi (2006) in their study on ergonomically sound work chair and table recommended 4 combinations of chair and table for short, medium and tall height individuals for both male and female subjects. For height range 140-150 cm, 150-160 cm, 160-170 cm and 170-180 cm the seat height and table height should be 40 cm+69 cm, 43 cm+72 cm, 46 cm+75cm and 49 cm+78 cm respectively.

Dhayni (2007) cited in her research that anthropometry is an integral part of human limitations and capabilities and the fact that the anthropometric dimensions vary from individual to individual. It is essential to consider the range of variability in general body size, gender, racial difference while designing the tools and equipments.

AS/NZS 4442:1997 – "*Office desks*" and AS/NZS 4443:1993 – "*Workstations*" requires a minimum adjustable range of a work surface from a seated position of 610 mm to 760 mm: when standing, the required range increases to 900 mm to 1200 mm.

**Fig 2.1 Dimensions of workstation for sitting and standing work**




**Application of RSM**

Bengal and Bukchin (2002) proposed a new methodology for workstation design based on factorial experiments and RSM. RSM was utilized to optimize the design factors with respect to economic and ergonomic multi-objective measures. Factors that represent distance, angles, weights or other characteristics of task environment were taken as the experimental factors. The aim was to increase the throughput rate (capacity) of the workstation, as well as to create a suitable and adjustable ergonomic workstation that would accommodate a large percentage of the worker population. The result of the study revealed the best combination of all the experimental factors and response factors.

Iqbal *et al.* (2004) conducted an ergonomic study for designing optimum printing workstation for an electronic industry using factorial experiment and response surface methodology. The aim was to find the value of physical dimensions that gives the best performance for the workstation. Four performance measures were selected; the cycle time, the metabolic energy expenditure, worker's posture during the task and lifting limitations. The methodology used in this study consists of two parts. The first part was based on factorial experiments and handles discrete search over combinations of factor-levels for improving the initial solution. In the second part, the solution that was obtained earlier was further refined by changing the continuous factors by using response surface methodology. The result of this optimization study showed that the optimum value of physical dimensions gave a significant improvement for the performance measures of the workstation.

**2.3. Ergonomic interventions in work activities**

Saha *et al.* (1973) have suggested two types of rest pauses, one for light work and other for heavy work, viz. 10 min of rest followed by 30 min of light work and 30 min of rest followed by 10 min of heavy work. It was shown by a mathematical computation that such arrangement of work and rest periods would not only keep the level of physiological strain at an acceptable limit, but also high production with less physiological cost. Based on Spitzer formula Saha have prepared a table for determination of rest allowance of rest allowance based on heart rate responses during manual work. In a subsequent publication, Saha *et al.*

(1979) reiterated that the heart rate beyond 110 beats.min$^{-1}$ could produce undue physiological strain which might result in fatigue and consequently requires rest pause.

Kogi (1985) reported that participatory ergonomics plays very crucial role in improving workstations in small enterprises. Basic rules of workstation improvements widely applicable in small enterprises include: efficient material flow, easy reach, elbow height work, use of fixing and lifting devices, action information and autonomous group work. Selection and application of priority solutions cab be best done by organizing group work through each action program which proceeds through: study of potential actions, planning of practicable actions, agreeing on priorities, immediate changes by using local materials and skills and evaluation and follow ups. All these S-P-A-C-E steps play very important role in improvements.

Hagberg and Sundelin (1986) proposed benefits of rest intervals reporting that frequent rest intervals can assist in reducing the perception of postural discomfort, offering further support to the notion that postural variation and a break away from constrained postures can be effective in reducing or delaying the experience of musculoskeletal discomfort.

McNeill and Westby (1999) evaluated a manually operated machine for chipping cassava with six farmers and their physiological, postural, and subjective measurements were taken. Use of the machine resulted in drudgery and postural discomfort. Following an integrative design process and using appropriate anthropometric measurements, an improved adjustable prototype was developed which was again tested with the six farmers and six novice users. It was found to reduce discomfort and physiological strain, allowed a faster work-rate (with novice users) and was preferred by all users. The study demonstrated how ergonomics can play an important role in reducing drudgery and improving user satisfaction in technology development and transfer in developing countries.

Tirtayasa *et al.* (2003) conducted a study on manggure which is a manual process of producing copper blades. The craftsmen of manggur work for 6-8 hours a day, sitting on the floor with folded legs and hunched back. Because the craftsmen often complaint of musculoskeletal pain after a full day work, an ergonomic intervention was made by changing their usual working posture (the first working posture) into working on tables while sitting on the chair for one hour and alternately standing for half an hour (the second working posture). Treatment by subject design was applied to 22 randomly selected craftsmen. Resting heart rate and working heart rate were measured were measured using a stopwatch, and the number of musculoskeletal complaints were recorded with Nordic body map questionnaire. As a result, the second working posture caused a significant reduction in working heart rate, work pulse and no of musculoskeletal problems.

Sarder *et al*. (2006) conducted a study in an export garment manufacturing plant in South East Asia to evaluate the working conditions of the plant from an ergonomics/human factors perspective and to suggest possible solutions to management for implementation. The results indicated that the plant conditions were stressful, involving long work hours with poor safety and labor relations, and that work equipment and the physical workplace design were acceptable ergonomic practices. A low-cost solution, presented to management by the investigators, was implemented and, over a period of six months, seemed to be the dominant reason for significant improvements in throughput (14.6%), reduction in absenteeism (65 %), job satisfaction (40 %), decrease in employee turnover (75 %), and reduction in health complaints (50 %).

### 2.4 Effect on shelf life and economic benefits of using improved technology

***Aonla*** **preserve**

Tripathi *et al.* (1988) evaluated organoleptic quality of *aonla* products prepared from *banarasi* by the expert judges and observation concluded that more acceptability of *aonla* jam was observed after 45 days of storage and non significant decrease in quality was observed up to 135 days of storage. The *aonla* preserve also showed maximum acceptability after 45 days of storage that did not change up to 135 days of storage.

Daisy (2002) in her study observed that most of the nutrient constituents decreased during processing of *aonla* into *aonla* preserve. Acidity and ascorbic acid content decreases during processing, Total Soluble Solid (TSS), total and reducing sugar decreased during pricking and blanching, and then increased after steeping into sugar syrup of increased strength. pH content increased with processing, whereas moisture percentage first decreased after pricking, then, increased after blanching, and finally decreased after steeping into sugar syrup. The browning was observed more in preserve of *banarasi* than in preserve of *chakaiya.* Preserve prepared from *banarasi* fruit was liked more than preserved prepared from *chakaiya* fruit.

Sahu *et al.* (2010) conducted an experiment on *aonla* fruits of three cultivars (*banarasi, NA-7 and NA-10*) to investigate the quality and shelf life of *aonla* preserve during storage. Physico-chemical changes in *aonla* preserve were analyzed prior to storage and during storage of 30 days intervals. The preserve of *banarasi aonla* cultivar treated with salt + alum proved to be superior recording the maximum TSS (57.90%), ascorbic acid (208.50 mg/100g), reducing sugar (53.67%), total sugar (56.71%) and while, *at par* acidity (5.25%) at the end of storage period *i.e.* six months. The organoleptic score (6.80/ 10.00) and color score (8.00/ 10.0) were also found ideal at the end of storage period *i.e.* five months under room condition.

**Techno-economic feasibility of machine**

Sethi (1995) conducted a study on existing techniques and drudgery involved in papad and wadia making and developed and evaluated a cost effective device for cottage industries. The study revealed that the use of wadi making saved 73.5 per cent of time where as by the papad maker it was 31.4 percent. Output capacity of workers increased four times with the use of wadi maker and almost two times in papad maker. Organoleptic evaluation indicates that the product prepared by wadi maker was found to be more acceptable than manual method, but the results were more or less comparable for papad prepared by papad maker and manual method. Physiological stress of the body *i.e.* blood pressure, grip force, heart rate and perceived exertion indicated that there was significant difference in manual methods and makers. Acceptability of both the makers was tested under field conditions and was widely accepted.

Ganachari *et al*. (2010) designed and developed a hand-operated machine for the removal of seed from the fresh *aonla* fruit. The machine consisted of fruit seat, fruit punching rod, handle and frame to hold all the parts. The machine had a capacity of 16.66 kg per hr or 530 fruits per hr. The waste that included the pulp and juice was recorded to be 10 percent. The cost of the machine calculated was Rs. 650, in which only the seat and the punching rod were made of stainless steel and all others parts were of mild steel. The cost of operation, including the labor cost and depreciation was Rs.10.20 per hr. The *aonla* fruit after removal of seed by the machine was used for the production of intermediate moisture food by osmotic dehydration which had a good consumer acceptance.

Hence, from the above literature reviewed it is clear that there are no particular studies on *aonla* pricking units and the difficulties faced by the workers involved in these units. So the workers remained deprived of working with improved technology in suitable work environment. This study is therefore, an attempt towards betterment of the *aonla* pricking units and workers by assessing their existing working procedures and work environment and then bringing appropriate ergonomic interventions.

**CHAPTER–III**

# METERIALS AND METHODS

This section presents the procedure adopted for conducting the present investigation. The research study was conducted in following three phases:

**Phase I** **(Survey Work): Field survey to study existing conditions of *aonla* pricking small- medium enterprises (SMEs)**

**Phase II** **(Experimental Work): Ergonomic evaluation of conventional and improved methods of *aonla* pricking, user's acceptability of the machine and organoleptic quality of the product**

**Stage I**: Ergonomic evaluation of conventional and improved method of *aonla* pricking

**Stage II:** Acceptability and economic benefits of the *aonla* pricking machine

**Stage III**: Analysis of organoleptic quality, vitamin C content and water activity of the preserve

**Phase III** **(Experimental work): Development of workstation, optimization of process parameters using RSM and application of WISE methodology**

**Stage I:** Development of prototype workstation for *aonla* pricking machine

**Stage II**: Optimization of process parameters using RSM

**Stage III:** Improvements for preserve making enterprises as per WISE methodology

The research procedure followed has been distinctly described under the following sub-heads:

1. Locale of the study
2. Sampling procedure
3. Variables and their measurements
4. Tools and techniques of data collection
5. Development of devices/techniques and specifications of used tools and methodologies
6. Analysis of data

**1. Locale of the study**

The first phase was undertaken in four *aonla* processing SMEs which were certified by Fruit Products Order (FPO) from Hisar, Kaithal and Jind districts of Haryana state namely:

1. Shree Mahakali Food Products, Hisar
2. Kamal Enterprise, Mittal Aachar factory, Hisar
3. Sirohi Farms, Distt. Kaithal
4. Rasal Preserves, Distt. Jind

In second phase, Stage I was carried out in the Department of Family Resource Management, College of Home Science and in the Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, CCSHAU, Hisar. Stage II was undertaken in previously selected enterprises and departments. Stage III was carried out in the Department of Processing and Food Engineering, COAE&T, CCSHAU, Hisar.

The third phase, Stage I and II were carried out in department of Processing and Food Engineering, COAE&T, CCSHAU, Hisar.

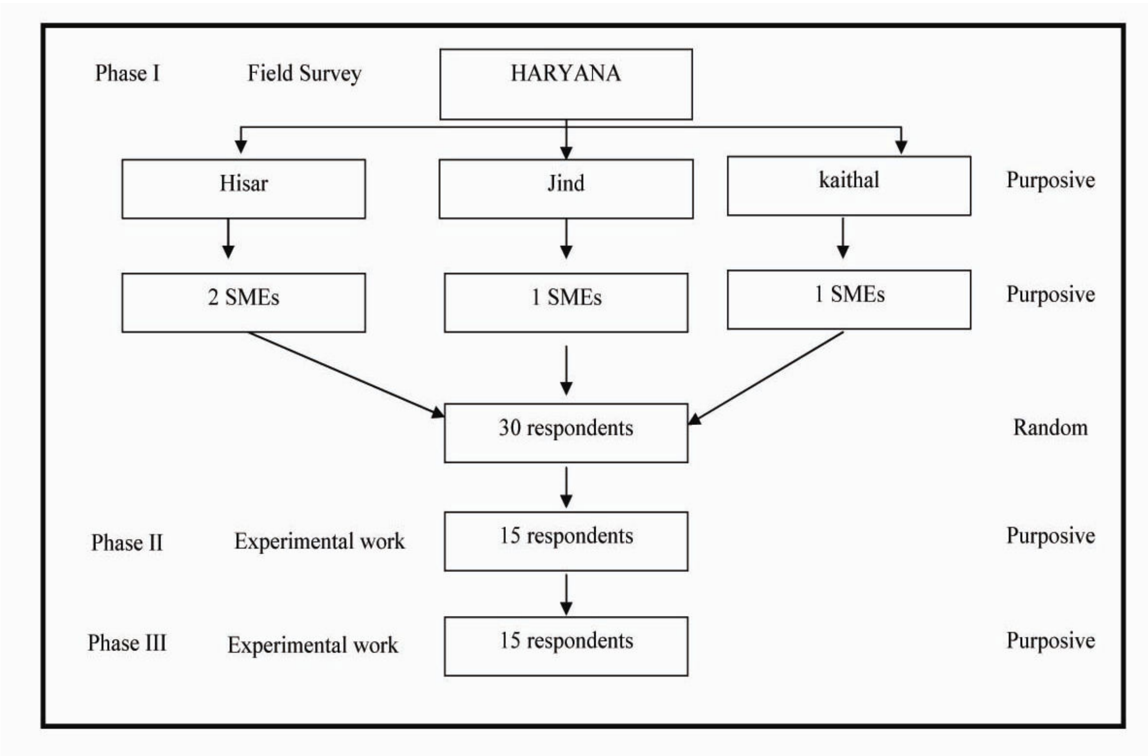
**2. Sampling procedure**

For the first phase, a sample of 30 women workers from 4 selected preserve making enterprises engaged in pricking task were randomly selected and interviewed.

For second phase, for Stage I and II, a total sample of 15 women workers from previously selected 30 women workers were selected on the basis of their good health status and willingness to contribute to the research work. In stage III, the organoleptic quality of the product was tested with teachers and students of COHS and COAE&T.

For third phase, for stage I, the 30 women workers of phase first were continued and their anthropometric dimensions were taken for designing the workstation and for conducting experiment on workstation workers in stage II, 15 women workers of phase second were continued. The sample design for the present investigation is depicted in fig 3.1.

**Fig. 3.1 Sample Design**



## 3. Variables and their measurements

For phase II, the variables selected and their measuring tools/techniques were

**Table 3.1: Variables and their measurements**

| Variables | Measuring tools and techniques |
|---|---|
| **Independent Variables** | |
| **Physical parameters** | |
| Anthropometric measurements | Anthropometric kit |
| **Environmental parameters** | |
| Temperature | Thermometer |
| Relative Humidity | Hygrometer |
| Light (general lighting conditions in the units) | Lux meter |
| **Intermediate Variables** | |
| Posture | Through application of Response Surface Methodology (Box and Behnken1951) |
| Light (the range set up for experimental work) | |
| Time | |
| **Dependent Variables** | |
| User's acceptability | Interview schedule developed |
| Safety and comfort | Schedule developed |
| Productivity of the machine | Schedule developed |
| Quality of the product | Total sensory evaluation<br>Vitamin C (ascorbic acid)<br>Water activity estimation |
| Ergonomic parameters | Worksheet developed |

## I. Independent variables

**Physical parameters**

**a)** **Body weight:** It the vertical force exerted by a mass as a result of gravity. it is an indication of physical fitness of the person.

b) **Body height:** It is the vertical distance from the floor to the top of the head, measured while the subject stands erect, looking straight ahead.

c) **Body composition:** It refers primarily to the distribution of muscles and fat in the body and its measurement play a very important role in determining health status of individuals.

d) **Body mass index:** It is a key index having relationship of weight to height.

**Environmental parameters**

**a)** **Temperature:** It is the degree of hotness or coldness of the atmosphere. For work, the comfortable range of atmospheric temperature is taken to be about 20 to 25 degree celsius with an average of 23°C.

b) **Relative humidity:** It is an index of amount of water vapors in the air. It is simply percentage saturation of air, which is less than or equal to 100. Relative humidity of 40-50 percent makes one comfortable in winters while in summers 40-60 percent is normal.

c) **Light:** It refers to the general lighting conditions in the enterprises in which workers work. For precise work like pricking with hand tool light should be in the range of 500-1000 lux.

**II. Intermediate variables**

a) **Posture:** Posture is the position of the body while performing the work. The three types of posture *i.e.* standing , sitting on chair and low stool sitting with respective position of pricking tools on suitable platform were evaluated to find out the best working posture for long working hours.

**b) Light:** Three different levels of lighting *i.e.* 100 lux, 300 lux, 500 lux that can be managed while working in the enterprises were evaluated with women workers to find out the best lighting conditions.

**c) Time:** It is the measurable period over which an action or process continues. The pricking activities with all the tools were carried out for 3 different durations *i.e.* for 1 hour, 2 hour, 3 hour to find out the duration that best suits the workers without causing undue fatigue.

All these 3 parameters were linked to each other using RSM to find the best combination of posture-time-light and the best combination then was planned to be implemented in the preserve making enterprises.

**III. Dependent Variables**

a) **User's acceptability:** The machine developed was tested for its acceptability by its ultimate users.

b) **Safety and comfort:** It means that the working with all the tools doesn't impose any health hazards especially musculoskeletal disorders, eye aches and small hand tool injuries to the workers.

c) **Productivity of machine:** It refers to number/ kilograms of *aonla* that workers were able to prick using machine without development of fatigue.

**d) Quality of the product prepared:** It emphasizes that final product prepared under all the treatments was well accepted by consumers.

e) **Ergonomic parameters:** All the ergonomic parameters were carefully measured while working with both the conventional and improved tools.

**Table 3.2: Ergonomic parameters and their measurements**

| Parameters | Name of the instrument |
|---|---|
| **Physiological parameters** | |
| Heart rate | Polar heart rate monitor |
| Physical fitness index | Step-stool ergometer |
| Energy expenditure rate | 0.159 x Avg. Working HR (bpm) – 8.72 |
| Total cardiac cost of work (TCCW) | Cardiac cost of work + Cardiac cost of recovery |
| Physiological cost of work (PCW) | TCCW / Total time of the activity |
| Force applied | Load cell |
| Oxygen consumption rate (OCR) | Formula not applicable for this research |
| **Biomechanical parameters** | |
| Grip strength | Grip dynamometer |
| Posture | Flexi curve, OWAS, RULA |
| Angle of deviation | Goniometer |
| **Psycho-physiological parameters** | |
| Perceived exertion | RPE scale |
| Musculoskeletal discomfort | Human body map (BPDS), VAD scale (ODS) |
| | Nordic questionnaire |

**4. Tools and techniques of data collection**

**Phase I:** Field survey was conducted with the help of interview schedule and observational studies (Annexure II). It covered various aspects like physical condition of the units, personal and working profile of workers, description of work task, description of processing tools and techniques, work accidents and injuries and protective measures adopted by units.

**Phase II**: Worksheets were developed containing all the ergonomic parameters and were filled during the activity (Annexure III). Interview schedules was developed to find out acceptability of machine by the users (Annexure VII), safety and comfort of workers while working on the machine and economic benefits associated with the use of machine (Annexure VIII). Hedonic scale proforma (Annexure X) and observation sheets were used for vitamin C (Annexure XI) and water activity estimations.

**Phase III:** Worksheet was developed for taking anthropometric dimension of the workers (Annexure XII) and design expert was used to obtain the results of the experiment conducted using RSM.

**Experimental procedure for ergonomic evaluation of pricking activity using conventional and improved methods**

**Phase II: Stage I**

For selection of workers for the experiment the health status of the workers was assessed in terms of their physical fitness, body mass index and body composition.

**Physical Fitness Index (PFI)**

For determining the physical fitness of subjects, wooden step stool ergometer was used. Selected subjects were given rest for some time and then resting heart rate was measured with the heart rate monitor. After the complete rest, the subjects were asked to perform the steeping activity on the ergometer for a maximum of 5 min with a uniform stepping rate of 30 steps/min. Then the recovery heart rate was recorded after every 1 min for a period of 5 min. PFI was measured using the following formula (Varghese *et al.,* 1995):

$$\text{Physical Fitness Index (PFI)} = \frac{\text{Duration of stepping (sec)}}{\text{Sum of } 1^{st}, 2^{nd} \text{ and } 3^{rd} \text{ min recovery heart rate}} \times 100$$

**Table 3.3: Interpretation of health status of the subjects as per the PFI**

| Scores | Physical fitness of the subjects |
|---|---|
| Upto 80 | Poor |
| 81-100 | Low average |
| 101-115 | High average |
| 116-135 | Good |
| 136-150 | Very good |
| Beyond 150 | Excellent |

**Body Mass Index (BMI)**

BMI was derived by measuring weight and height of the subjects using Quetelet's Index by the following formula given by Garrow (1981).

$$\text{Quetelet's Index} = \frac{\text{Weight (kg)}}{\text{Height}^2 \text{ (m)}}$$

**Table 3.4: Grading of health status on the basis of BMI**

| Scores | Presumption Diagnosis |
|---|---|
| 16.0 | CED* grade- III (Severe) |
| 16.0-17.0 | CED grade- II (moderate) |
| 17.0-18.5 | CED grade-I (mild) |
| 18.5-20.5 | Low weight normal |
| 20.5-22.5 | Normal |
| 25.0-30.0 | Obese grade-I |
| 30.0 | Obese grade- II |

CED= Chronic energy deficiency

**Body composition**

It was estimated in terms of ectomorphic, mesomorphic and endomorphic population using the scores of Quetelet's Index.

**Table 3.5: Interpretation of body type on the basis of BMI**

| Body Type | Quetelet's Index Score | Description |
|---|---|---|
| Ectomorph | 20 | Slender, very thin body |
| Mesomorph | 20-25 | Athletic type body |
| Endomorph | 25 | Abdominal physical type |

After ascertaining the health status of the workers, the experiment *i.e.* the ergonomic evaluation of conventional and improved methods of *aonla* pricking was carried out. The experiment was carried out in the months of February to April. The conventional tools evaluated were fork and hand tool and hand operated *aonla* pricking machine was introduced as improved method of pricking (Annexure I). 3 different postures were evaluated while working with all the three tools namely: sitting on ground (S1), squatting (S2) and standing (S3). The experiment was conducted for duration of 20 minute with all the 3 tools in 3 different postures with 15 women workers. 3 replications were taken in each experiment and their mean was calculated to get the final value. The various ergonomic parameters were recorded in terms of physiological, biomechanical and psycho-physiological responses of workers while performing the task.

**Measurement of physiological parameters**

It was used to determine the workload on the workers in form of cardio-respiratory responses and was measured in terms of heart rate (HR), energy expenditure rate (EER), and physiological cost of work (PCW) during the pricking task.

The workload on the workers after the completion of the pricking activity was found out on the basis of HR and EER as given by Varghese *et al*. (1995).

**Table 3.6: Workload classification**

| Workload | HR (beats.min$^{-1}$) | EER(kJ.min$^{-1}$) |
|---|---|---|
| **Very light** | Up to 90 | Up to 5.0 |
| **Light** | 91-105 | 5.1-7.5 |
| **Moderately heavy** | 106-120 | 7.6-10.0 |
| **Heavy** | 121-135 | 10.1-12.5 |
| **Very heavy** | 136-150 | 12.6-15.0 |
| **Extremely heavy** | 150 | 15 |

**Heart rate (HR)**

Heart rate of the workers was measured with the help of polar heart rate monitor at rest, during the period of the activity and recovery thereafter. Values of resting, average and recovery heart rate were averaged out each time to make a final assessment.

From the values of heart rate following parameters were calculated using their respective formulas:

Energy expenditure rate (EER) (kJ.min$^{-1}$) = 0.159 x Avg. Working HR (bpm) – 8.72

Cardiac cost of work (CCW) (beats) = (Avg. working HR – Avg. Resting HR) x Duration of activity.

Cardiac cost of recovery (CCR) (beats) = (Avg. Recovery HR–Avg. Resting HR) x Duration of activity.

Total cardiac Cost of work (TCCW) (beats) = CCW + CCR.

Physiological cost of work (PCW) (b.min$^{-1}$) = TCCW / Total time of the activity.

The average scores of all the 15 workers were computed using mean and standard deviation and were recorded to obtain the final values.

**Measurement of biomechanical parameter**

The stress on the musculoskeletal system of the workers while pricking task was assessed in terms of grip fatigue, postural deviation of body parts and angle of spine deviation using following tools and techniques:

**Grip fatigue**

It is the stress experienced by the grip muscles during or after an activity. It was measured using grip dynamometer. Grip strength of the workers was measured before the start of the activity separately with right and left hand. After the completion of the activity, the grip strength was again measured. The grip fatigue was calculated using the following formula:

Grip fatigue (%) = Sr-Sw x 100 /Sr

Sr = strength of muscles in rest.

Sw = strength of muscles in work.

Reduced muscular strength during activity is an indicator of muscular fatigue because of the activity.

**Postural discomfort**

It is the discomfort / body pain arising as a result of the working posture. It was measured using following low cost tools:

**Flexi curve:** It was used to measure the angle of deviation (degree) between the normal spine curve and maximum deviated posture. The flexi curve was mounted to the contour of the spine and immediately drawn on a plain paper to measure the angle of deviation. The angle of bent of the back during the performance of the activity was measured and compared with the normal bent of the back and the angle of the deviation was determined by subtracting the normal angle of bent from the angle of bent during the bending posture.

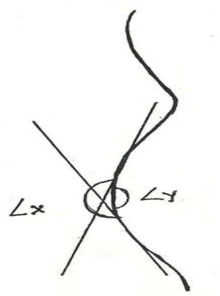


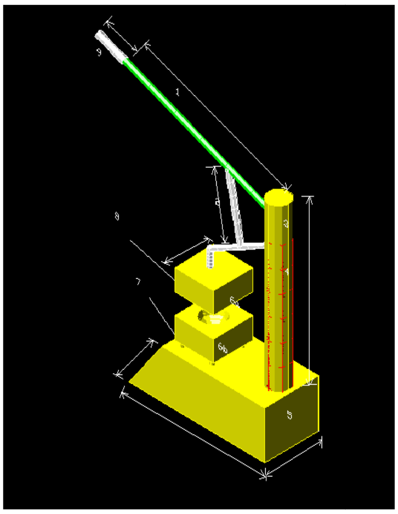
**Plate 3.1: Conventional and improved methods of pricking**

**Conventional methods of *aonla* pricking**

**Fork**

**Hand tool**

**Improved method of *aonla* pricking**



**Hand operated *aonla* pricking machine**

**Plate 3.2: Different postures adopted by women workers while using conventional and improved methods of pricking**

**With fork**

**Sitting on ground** | **Squatting** | **Standing**



**With hand tool**

**Sitting on ground** | **Squatting** | **Standing**



**With machine**

**Sitting on ground** | **Squatting** | **Standing**



## Plate 3.3: Equipment used for experimental work


**Lux Meter**

**Polar heart rate monitor**


**Load cell**

**Goniometer**


**Grip dynamometer**

Required angle = x

Measured angle = y

Required angle (x) = 360-y

In addition to flexi curve, the angle of deviation was measured using:

**Goniometer:** Goniometer was used to measures an angular deviation of wrist during the pricking task.

**RULA**

RULA stands for Rapid upper limb assessment method given by Atamney & Corlett, 1993. It is a survey method developed for ergonomics investigations of workplaces where work related upper limb disorders are reported. It uses the diagram of body posture including movement of arms, wrist, neck, trunk and legs by scoring method including three scoring table to evaluate the level of exposure of risk factors. A coding system is used to generate an action list which indicates the level of interventions required to reduce the risk of injury due to physical loading on the operator. A video of pricking task was taken, then cropped and used to fill observation sheet and then pricking task was numbered to suggest corrective actions and necessary changes. (Annexure IV)

**Table 3.7: RULA action sheet**

| **Action Level** | **Score** | **Interpretation** |
|---|---|---|
| 1 | 1-2 | Posture is acceptable if it is not maintained or repeated for long time |
| 2 | 3-4 | Further investigation is needed and change may be required |
| 3 | 5-6 | Investigation and changes are required soon |
| 4 | 7-8 | Investigation and changes are required immediately |

**OWAS**

OWAS stands for Ovako working posture analysis given by Karhu *et al.,* 1977. It is a simple observational method for postural analysis especially that of back, lower and upper extremities and load. Video during pricking action, showing different movements of worker was recorded and then was cropped after every 10 seconds to get snapshots for analysis of posture. The snapshots were analyzed to fill the score of OWAS sheet. The OWAS method uses the concept of number to represent posture with an associated coding system. The jobs with the involvement of high risk were numbered higher and those with the less risk involvement were numbered low and thereafter immediate corrective actions and necessary changes were recommended. (Annexure V)

**Table 3.8: OWAS Action Sheet**

| OWAS category | Description |
|---|---|
| Action category 1 | Work postures are usually considered with no particular harmful effects on musculoskeletal system. No action is needed to change work posture. |
| Action category 2 | Work postures have some harmful effects on musculoskeletal system. Light stress, no immediate action is necessary, but changes should be considered in future planning. |
| Action category 3 | Work postures have distinctly harmful effects on musculoskeletal system. The working method involved should be changed as soon as possible. |
| Action category 4 | Work postures with extremely harmful effects on musculoskeletal system. Immediate solutions should be found to change this posture. |

**Measurement of Psycho-physical parameters**

In addition to cardio-respiratory and biomechanical responses, the psycho-physical responses of the workers while performing pricking activity were also recorded in terms of RPE, VAD, BPDS and NMQ as given below:

**Rating of perceived exertion (RPE scale)**

The RPE scale given by Varghese *et al*., 1995 was used to measure the intensity of exertion. It is subjective expression of feelings of workers towards the activity *i.e.* how easy or difficult the subject finds his activity. It is based on physical sensation a person experiences during an activity including increased heart rate, increased sweating and muscle fatigue. This scale now has been accepted as a practical method for rapid appraisal of all occupational work. In this scale, scores are assigned at 5-point continuum ranging from 1-5 *i.e.* very light exertion (1), light exertion (2), moderate heavy exertion (3), heavy exertion (4), and very heavy exertion (5). The weighted mean score was derived to reach the conclusion.

**Visual analogue discomfort scale**

For the assessment of overall discomfort rating, a psycho-physical rating scale which is an adaptation of Corlett and Bishop technique, 1976 was used. It is used to determine the discomfort during the activity and doesn't attempt to measure the severity and intensity of the pain. It is a 10 point scale, 0 being the lowest point showing no discomfort and 10 being the uppermost point showing the extreme discomfort. The weighted mean score was derived to reach the conclusion.

**Table 3.9: Visual analogue discomfort scale**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| No Discomfort | | | | | | | | | | Extreme Discomfort |

**Human Body map**

It is used to measure the localized discomfort, musculoskeletal discomfort and intensity of pain in different body parts resulting from postural discomfort. Body part discomfort score (BPDS) is obtained using human body map given by Corlett and Bishop, 1976. In this technique the body is divided into a number of regions. After a bout of work the subjects were asked to indicate body parts that were most painful. After noting these, the next painful parts were asked and on till the workers indicate no further parts. In this scale, scores are assigned at 5-point continuum ranging from 1-5 *i.e.* very light exertion (1), light exertion (2), moderate heavy exertion (3), heavy exertion (4), and very heavy exertion (5). The weighted mean score was derived to reach at the conclusion.

**Nordic musculoskeletal questionnaire**

Nordic musculoskeletal questionnaire developed by Kuorinka *et al.,* 1987 was used to gather information on current pain in immediate past 7 days and previous pain in last 12 month. The questionnaire consists of series of objective type questions with multiple type responses. The face to face interview was done to gather required information as it was thought to be more reliable in obtaining accurate information. The average scores of all the 15 workers were computed using weighted mean and were recorded to obtain the final values. (Annexure VI)

**5. Development of devices/techniques and specifications of used tools and methodologies**

**Phase III: Stage I**

For proper working with machine, an ergonomically designed sit -stand workstation was developed considering the anthropometric dimensions of the user's population. For this purpose, anthropometric dimensions of 30 women workers of phase first were taken.

**Design and development of workstation for *aonla* pricking machine**

The workstation consisted of platform made up of wooden blocks with a slot for sensor mounting (load cell), a rack system for up and down movement of platform, supporting and base frames and pillars made up of iron.

**Design consideration of the workstation**

1. Allow to alternate the posture-An increasingly common approach is sit- stand workstation. The whole surface was designed to move up and down using rack system.
2. All the supplies, tools should be within the easy reach of workers hence to be provided on the work table. Designed worktable was having optimum surface area containing machine, tubs on either side for unpricked and pricked *aonla*.

3. Improving the sequence of work- Since *aonla* has to be pricked and placed in Teflon blocks of machine with left hand. So container for unpricked *aonla* was placed on left side and for pricked *aonla* on right side.

4. The workstation should also be sized to allow for the full range of movements required to perform assigned task. Hence, was developed according to the anthropometric dimensions of the women workers.

5. The equipment was designed for women workers as in most of the cases equipment designed for women workers suits to men workers as ergonomic characteristics like anthropometric dimensions, physiological and biomechanical parameters of women workers are less than men workers. So, the workstation suitable for women would be suitable for men workers (Gite and Singh, 1997).

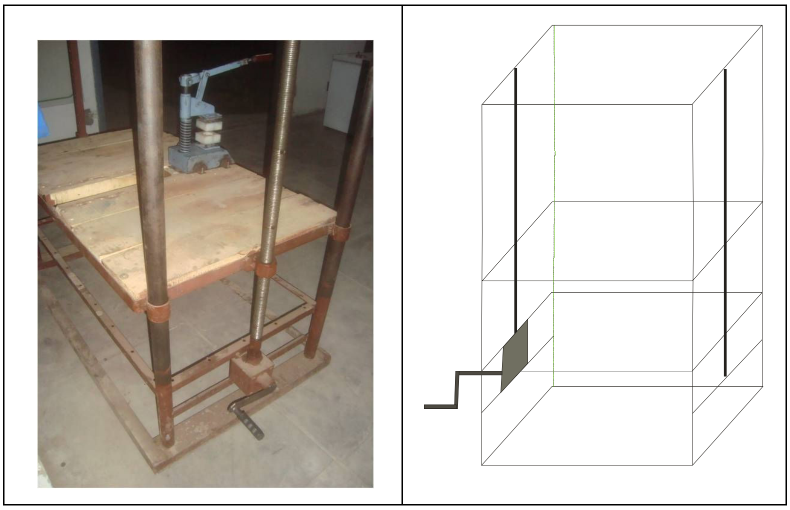
**Design specifications of workstation**

1. Platform, top frame and base frame dimensions = 1320 mm x 780 mm
2. Lifting rack diameter = 60 mm
3. Supporting pillars dimensions = 1620 mm
4. Foot rest height = 144 mm
5. Slot for sensor mounting on platform = 144 mm x 48 mm x 72 mm
6. Height of full workstation = 1620 mm
7. Adjustable height of workstation=1620 mm
8. Dimensions of lifting arrangements = 300 mm

**The operation of workstation**

With the clockwise movement of the handle provided on the base of lifting rack, the workstation moves upwards and with the anti-clock movement of the handle the workstation moves downwards and can be adjusted according to the working height of user's population.

**Fig 3.2: Workstation for the machine**



**Phase II: Stage III**

In order to assess the quality of the final product, three types of preserve were prepared with variation in pricking tools (fork, hand tool and machine). *Chakaiya* variety of *aonla* was used for the experiment. The quality of the prepared samples then was judged using hedonic scale, ascorbic acid content, and water activity data.

**Method used for preserve preparation**

Preserve was prepared from *aonla* fruits pricked under three treatments *i.e.* with fork, hand tool and machine using a standard method given by Rakesh *et al.* 2004.

**Sensory Evaluation**

The organoleptic quality of the different samples of preserve thus prepared was determined with the help of a 9 member consumer panel consisting of teachers and students of COHS and COAE&T using 9 point hedonic scale. The average scores of all the 9 panelists were computed and were recorded for each sample.

**Ascorbic acid Estimation**

Ascorbic acid in the samples was estimated by using titration method.

**Water activity estimation**

Water activity is a critical factor that determines shelf life of a product and is most important factor in controlling spoilage. Most bacteria do not grow at water activities below 0.91, and most molds cease to grow at water activities below 0.80. By measuring water activity, it is possible to predict the potential sources of spoilage and shelf life of a food product. It is measured using water activity analyzer.

**Phase III: Stage II**

**Application of RSM for optimization of process parameters**

In statistics, response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The method was introduced by Box and Behnken in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response.

**The process parameters along with their range taken for optimization were:**

**Range of process parameters**

| | | |
|---|---|---|
| Posture | : | Sitting on low stool (200mm), sitting on chair (600mm) and standing (1000mm) |
| Light | : | 100-300-500 lux |
| Time | : | 1-2-3 hr |

The responses selected for the experimental work were both ergonomic and economic parameters. The ergonomic parameters selected were heart rate and body part discomfort score and economic parameters selected were productivity of the workers while using all the tools and total sensory score of prepared preserves.

A total of 17 experiments showing different combinations of process parameters were carried out in the lab to obtain the best combination that would yield the most desired results.

**Phase III: Stage II**

**Application of WISE for improving working conditions**

Work Improvement in Small Enterprise (WISE) also known as 'Higher productivity & a better place to work', is a program developed by the International Labour Organization (ILO) (1996) to assist small and medium scale enterprises (SMEs) in improving working conditions and productivity using simple, effective & affordable techniques**.** WISE was used to suggest the improvements for the preserve making units in terms of material storage and handling, workstation design and work environment and work organization. These improvements were thought to lead to the betterment of preserve making units.

**7. Analysis of data**

The physiological and biomechanical parameters were analyzed using mean and standard deviation, weighted mean was used to analyze the psycho-physical parameters. Response surface methodology was used to link the ergonomic (heart rate and body part discomfort score) and economic (productivity and total sensory) parameters.

## CHAPTER–IV

## RESULTS

The results of the study are presented under following subheadings:

4.1 Working conditions of *aonla* preserve making SMEs and work profile of workers
4.2 Ergonomic evaluation of conventional and improved methods of *aonla* pricking, user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared
4.3 Development of workstation, optimization of process parameters using RSM and application of WISE methodology

### 4.1. Working conditions of *aonla* preserve making SMEs and work profile of workers

Working conditions of *aonla* preserve making SMEs and work profile of workers were studied through field survey and walk through investigation of all the four *aonla* preserve making enterprises. The results have been presented under environmental working conditions and work profile of workers which are exhibited in table 4.1-4.3 and fig 4.1-4.6.

**Environmental working conditions of the workplaces of *aonla* preserve making units**

The comfortable environmental parameters at the workplace help to perform the activity easily and lead to increase in the work output. Hence, the environmental parameters at the workplace were studied which included light, temperature, humidity and noise levels. Table 4.1 reveals that all the four enterprises were having the lighting both artificial and natural in the range of 225±64.5 lux and 262±25.0 lux which was much below the recommended value of 500-1000 lux as *aonla* pricking is considered a precise activity. The temperature within all the units was found to be 29.5±1.9 $^0$C which was very high as compared to the recommended value. This indicates that the working environment was hot and not very comfortable for the women workers. However, humidity and noise levels were found to be 56.5±2.6 percent and 57±7.2 db respectively which were within the recommended range.

**Table 4.1: Environmental condition of the workplaces of *aonla* preserve making units**

**(n=4)**

| Environmental Parameters | 1$^{st}$ SME | 2$^{nd}$ SME | 3$^{rd}$ SME | 4$^{th}$ SME | Mean ± SD | Recommended Values* |
|---|---|---|---|---|---|---|
| **Light (lux)** | | | | | | |
| **Artificial** | 150 | 200 | 250 | 300 | 225±64.5 | 500-1000 |
| **Natural** | 250 | 250 | 250 | 350 | 262±25.0 | |
| **Temperature($^0$C)** | 28 | 30 | 32 | 28 | 29.5±1.9 | 20-24 |
| **Humidity (%)** | 59 | 56 | 53 | 58 | 56.5±2.6 | 40-60 |
| **Noise (db)** | 55 | 65 | 48 | 60 | 57±7.2 | 45-65 |

*Grandjean (1978)

A walk though investigation of all the SMEs given in table 4.2 reveals that all the four enterprises were running in 1-2 poorly designed rooms, having inadequate ventilation, poor hygiene, drainage and unorganized storage facilities. There were no defined workstation in all the units and workers were carrying out the pricking task in awkward postures mainly sitting posture on ground with folded legs and hunched back. Workers in all the units were using conventional tools having improper grip and sharp pricking edges and were not using any protective measures to safeguard the fingers from sharp pricking edges of tools and consequently, were injured by pricking tools.

**Table 4.2:Observations and walk through investigations of *aonla* preserve making units**

(n=4)

| Parameters | SME 1 | SME 2 | SME 3 | SME 4 |
|---|---|---|---|---|
| **No of rooms** | **1** | **2** | **2** | **1** |
| **Poor Ventilation** | √ | √ | √ | √ |
| **Poor Hygiene** | √ | √ | √ | √ |
| **Poor Drainage** | √ | √ | √ | √ |
| **No Proper Storage Areas** | √ | √ | √ | √ |
| **No Workstation** | √ | √ | √ | √ |
| **Awkward Posture** | √ | √ | √ | √ |
| **Use of Conventional Tools** | √ | √ | √ | √ |
| **No Protective Measures** | √ | √ | √ | √ |

**Work profile of workers**

The information pertaining personal and work profile of workers in pricking task (table 4.3) reveals that the mean age, weight and height of the workers was found to be 29.8 yrs, 50.6 kg and 157.6 cm respectively. All the workers were laborers and unskilled. Their work started at 9 a.m. and continued till 5 p.m. They used to work for 50-60 hrs per week and 7-8 hrs per day. They were provided with only one main break of one hr for lunch, however, few irregular rest pause were also given. In the morning hours workers were able to prick 4-5 kg *aonla*/hr and this capacity reduced to 2-3 kg *aonla*/hr in evening hours indicating that with time workers were developing fatigue.

**Table 4.3: Personal and work profile of the *aonla* pricking workers**

**(n=30)**

| | Characteristics | Mean ± S.D. |
|---|---|---|
| **Personal profile** | Age (years) | 29.8±6.0 |
| | Weight (kg) | 50.6±4.6 |
| | Height (cm) | 157.6±4.7 |
| **Work profile** | Undertaken any training | No |
| | Time to begin work | 9 a.m. |
| | Time to end up work | 5 p.m. |
| | Working hrs per day | 50-60 hrs/week |
| | Working hrs per week | 7-8 hrs/day |
| | Output in morning hrs | 4-5 kg/hr |
| | Output in evening hrs | 2-3 kg/hr |
| | Number of breaks provided | 1 |

Worker's perception about the pricking task given in fig 4.1-4.4 exhibit that maximum number of the workers (43 %) were having average duration of 2.2 yrs on the pricking task. Most of the workers (85 %) felt that pricking task was labour intensive and physically demanding and they were feeling exhausted at the end of the working day. They also reported difficulties in the existing method of pricking which were attributed to poor work environment, improper working tools and long working hours in unnatural posture and lack of proper workstation.

**Workers perception about the pricking task (n=30)**

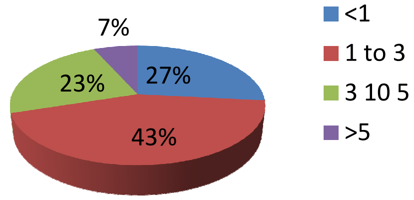


**Fig 4.1:Total number of years in pricking task**

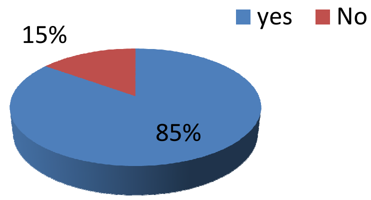


**Fig 4.2: Labour intensive pricking task**

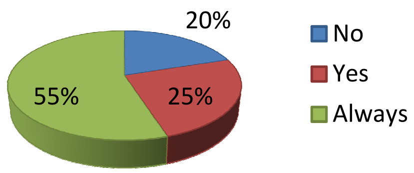


**Fig 4.3: Feeling of exhaustion after pricking task**

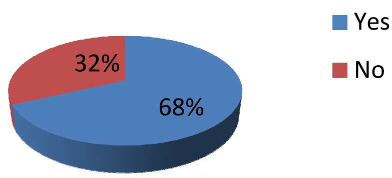


**Fig 4.4: Difficulty in existing methods of pricking**

Accidents and injuries during the pricking task have been presented in fig 4.5 and 4.6. Workers of all the 4 units were facing minor finger injuries from sharp pricking edges of the hand tools with a recovery period of 4-5 days. This was due to poor lighting levels in the units. Majority of the workers suffered from the cuts (96 %) from sharp edges of pricking tools followed by symptoms like irritation (88 %), laceration (75 %), numbness (63 %) etc.

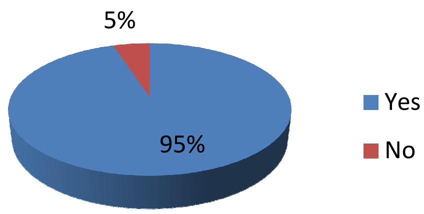


**Fig 4.5:Accidents and injuries in existing methods of pricking**

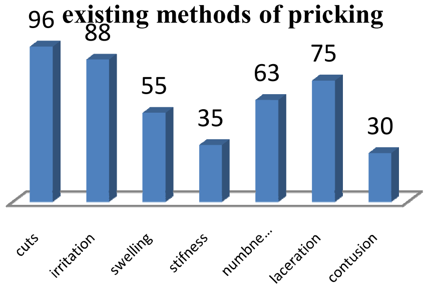


**Fig 4.6: Injuries to workers in existing methods of pricking**

## 4.2 Ergonomic evaluation of conventional and improved methods of *aonla* pricking, user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared

### 4.2.1 Ergonomic evaluation of conventional and improved methods of *aonla* pricking

The results of experimental work depicting ergonomic evaluation of conventional and improved methods of *aonla* pricking with 15 women workers in terms of physiological, biomechanical and psycho-physical parameters are presented in table 4.4-4.12.

Data in table 4.4 reveal physical characteristics and health status of the 15 women workers selected for the experimental study. The mean age, weight and height of the workers were found out to be 30.2 yrs, 55.4 kg and 158.6 cm respectively. Workers with normal body temperature and blood pressure were selected for the study. Their health status revealed that body mass index (21.9) and physical fitness index (127.6) of all the workers were within the normal range. The workers were having a mesomorph body type indicting a good body built.

**Table 4.4: Personal profile and health status of *aonla* pricking workers**

**(n=15)**

| Physical characteristics | Mean ± S.D |
|---|---|
| Age (years) | 30.2±5.7 |
| Weight (kg) | 55.4±4.4 |
| Height (cm) | 158.6±3.3 |
| Body Mass Index(kg/m$^2$) | 21.9±1.4 |
| Physical Fitness Index (PFI) | 127.6±4.7 |

#### 4.2.1.1 Physiological responses of the workers while working with conventional and improved methods of *aonla* pricking

The physiological /cardio-respiratory responses of the workers involved in *aonla* pricking were assessed by measuring heart rate, energy expenditure rate and physiological cost of work.

It is clear from the table 4.5 that while working with fork, the working HR was found to be maximum in squatting posture (84 b.min$^{-1}$), followed by standing posture (81 b.min$^{-1}$) and least in sitting posture (80 b.min$^{-1}$ ). The percentage increase in HR over the resting HR (71 b.min$^{-1}$) was found to be maximum in squatting posture (18 %), followed by standing posture (13.6 %) and least in sitting posture (13.3 %).

Similarly, while pricking *aonla* with hand tool, the working HR increased maximum in squatting posture (84 b.min$^{-1}$), followed by standing posture (81 b.min$^{-1}$) and least in sitting posture (80 b.min$^{-1}$). The percentage increase in HR over the resting HR was found to be maximum in squatting posture (17.5 %), followed by standing posture (13.3 %) and least in sitting posture (12.9 %).

Whereas, with *aonla* pricking machine, the working HR increased maximum in squatting posture (90 b.min$^{-1}$), followed by sitting posture (86 b.min$^{-1}$) and least in standing posture (84 b.min$^{-1}$). The percentage increase in HR over the resting was found to be maximum in squatting posture (25.5 %), followed by sitting posture (21.6 %) and least in standing posture (18.5 %).

A further perusal of table 4.5 reveals that with the conventional tools used, pricking task was found strenuous in squatting posture, followed by standing posture and least in sitting posture as it is evident from the obtained values of heart rate. Whereas, with machine, pricking task was found strenuous in squatting posture, followed by sitting posture and least in standing posture However, HR increased maximum while pricking with machine in squatting posture than the use of both the conventional tools in squatting posture.

A similar trend was observed in the values of energy expenditure rate (EER) and physiological cost of work (PCW). With fork, EER was found to be maximum in squatting posture (4.6 kJ.min$^{-1}$), followed by standing posture (4.1 kJ.min$^{-1}$) and least in sitting posture (4 kJ.min$^{-1}$). Similarly, with hand tool, EER was maximum in squatting posture (4.5 kJ.min$^{-1}$), followed by standing posture (4.1 kJ.min$^{-1}$) and least in sitting posture (4 kJ.min$^{-1}$). Whereas, with *aonla* pricking machine, EER increased maximum in squatting posture (5.4 kJ.min$^{-1}$), followed by sitting posture (5 kJ.min$^{-1}$) and least in standing posture (4.6 kJ.min$^{-1}$).

**Table 4.5: Physiological responses of workers while working with different tools in various postures**

**(n=15)**

| Tools/machine | Physiological responses | | | | | |
|---|---|---|---|---|---|---|
| | Treatments | Heart rate (HR) | | | EER (kJ.min$^{-1}$) | PCW (b.min$^{-1}$) |
| | | Working HR (b.min$^{-1}$) | Increase over base | % increase in HR | | |
| Fork | Sitting on ground | 80±0.6 | 9.5±1.5 | 13.3 | 4.0±0.08 | 11±1.8 |
| | Squatting | 84±0.5 | 12.8±1.3 | 18.0 | 4.6±0.09 | 14 ±1.4 |
| | Standing | 81±0.5 | 9.7±1.3 | 13.6 | 4.1±0.07 | 12±1.5 |
| Hand tool | Sitting on ground | 80±0.5 | 9.1±1.4 | 12.9 | 4.0±0.08 | 10±1.7 |
| | Squatting | 84±1.1 | 12.5±1.4 | 17.5 | 4.5±0.17 | 14±1.6 |
| | Standing | 81±0.4 | 9.5±1.2 | 13.3 | 4.0±0.07 | 11±1.5 |
| Machine | Sitting on ground | 86±1.2 | 15.4±2.2 | 21.6 | 5.0±0.19 | 18±2.8 |
| | Squatting | 90±1.8 | 18.1±2.5 | 25.5 | 5.4±0.29 | 21±3.3 |
| | Standing | 84±0.9 | 13.2±1.7 | 18.5 | 4.6±0.14 | 15±2 |

Heart rate at rest 71±1.4

Similarly, with fork, PCW was found to be maximum in squatting posture (14 b.min$^{-1}$), followed by standing posture (12 b.min$^{-1}$ ) and least in sitting posture (11 b.min$^{-1}$). With hand tool also, PCW increased maximum in squatting posture (14 b.min$^{-1}$), followed by standing posture (11 b.min$^{-1}$) and least in sitting posture (10 b.min$^{-1}$). Whereas, with machine, PCW increased maximum in squatting posture (21 b.min$^{-1}$), followed by sitting posture (18 b.min$^{-1}$) and least in standing posture (15 b.min$^{-1}$). Likewise, HR, EER and PCW were also found to be maximum in squatting posture, followed by standing posture and least in sitting posture while pricking with conventional tools. Whereas, with machine, EER and PCW were maximum in squatting posture, followed by sitting posture and least in standing posture.

#### 4.2.1.2 Biomechanical responses of the workers while working with conventional and improved methods of *aonla* pricking

The biomechanical responses of the workers while *aonla* pricking were measured in terms of grip fatigue and postural analysis. Postural analysis of pricking task in different working postures was done using low cost ergonomic assessment tools (EAT's) namely RULA and OWAS and by measuring spinal deviation during the pricking task.

**Grip fatigue**

Table 4.6 exhibits that the grip strength of both right as well as left hand of all the workers at rest was found to be 21.9 kg and 19.6 kg respectively. The grip fatigue of right hand after working with fork was found to be maximum in squatting posture (26.0 %), followed by sitting posture (24.2 %) and least in standing posture (20.9 %). Similarly, the grip fatigue of left hand after working with fork increased maximum in squatting posture (11.2 %), followed by sitting posture (10.2 %) and least in standing posture (8.2 %). However, the increase in grip fatigue of left hand was found to be very less as compared to the increase in grip fatigue of right hand after the pricking activity.

With hand tool also, the grip fatigue of right hand was found to be maximum in squatting posture (17.8 %), followed by sitting posture (13.6 %) and least in standing posture (13.2 %). The grip fatigue of left hand increased maximum in squatting posture (9.1 %) whereas have shown equal increase in sitting and standing postures (8.1 %). The grip fatigue of right hand was found to be higher as compared to the grip fatigue of left hand.

Whereas with machine, the grip fatigue of right hand was found to be maximum in sitting posture (17.8 %), followed by squatting posture (13.6 %) and least in standing posture (13.2 %). The grip fatigue of left hand increased maximum in sitting posture (5.1), followed by squatting posture (4.0) and least in standing posture (3.0). However, the increase in grip fatigue of left hand after pricking with machine was found to be almost half that of grip fatigue of left hand after pricking with conventional tools.

Thus, it may be concluded that while working with all the three tools, grip fatigue was found to be maximum for fork pricking. Grip fatigue was maximum with fork and hand tool in squatting posture and with machine in sitting posture.

**Table 4.6: Grip fatigue of hands while pricking with different tools in various postures**

**(n=15)**

| | Parameters | Sitting | | Squatting | | Standing | |
|---|---|---|---|---|---|---|---|
| | | RH | LH | RH | LH | RH | LH |
| Fork | At Rest (kg) | 21.9±2.2 | 19.6±2.0 | 21.9±2.2 | 19.6±2.0 | 21.9±2.2 | 19.6±2.0 |
| | After Work (kg) | 16.6±1.4 | 17.6±1.5 | 16.2±1.2 | 17.4±1.1 | 15.5±1.5 | 17.9±1.4 |
| | Reduction in Strength | 5.3 | 2.0 | 5.7 | 2.2 | 4.1 | 1.62 |
| | Grip Fatigue (%) | 24.2 | 10.2 | 26.0 | 11.2 | 20.9 | 8.26 |
| Hand tool | At Rest (kg) | 21.9±2.2 | 19.6±2.0 | 21.9±2.2 | 19.6±2.07 | 21.9±2.2 | 19.6±2.0 |
| | After Work (kg) | 18.5±1.5 | 18±0.7 | 18±1.2 | 17.8 ±0.6 | 19±1.5 | 18±0.6 |
| | Reduction in Strength | 3.0 | 1.6 | 3.9 | 1.8 | 2.9 | 1.6 |
| | Grip Fatigue (%) | 13.6 | 8.16 | 17.8 | 9.18 | 13.2 | 8.16 |
| Machine | At Rest (kg) | 21.9±2.2 | 19.6±2.0 | 21.9±2.2 | 19.6±2 | 21.9±2.2 | 19.6±2.0 |
| | After Work (kg) | 18±1.2 | 18.6 ±0.6 | 18.5±1.5 | 18.8±0.7 | 19±1.5 | 19±0.6 |
| | Reduction in Strength | 3.9 | 1.0 | 3.0 | 0.8 | 2.9 | 0.6 |
| | Grip Fatigue (%) | 17.8 | 5.1 | 13.6 | 4.0 | 13.2 | 3.0 |

RH- right hand, LH- left hand

**Postural analysis of workers using RULA and OWAS**

Musculoskeletal disorders are one of the leading problems that women are facing now a days due to awkward posture adopted during work and highly repetitive motions for longer periods of time. To assess the musculoskeletal problems of workers engaged in pricking task in different postures, low cost ergonomic assessment tools were used. The results are presented in table 4.7-4.9.

**Rapid upper limb assessment (RULA) outcomes**

There were few characteristics of the workplaces of all the four SMEs on the basis of which RULA scores were obtained which are given below:

1. No defined workstation, hence, task was carried out mostly by sitting on ground or rarely in squatting and standing postures.
2. Constrained and sustained work postures for prolonged time especially sitting posture with forward bent position of neck, back, flexed arms and folded legs, which places workers at risk of MSDs.
3. Task was highly repetitive and done manually, characterized by fast and repetitive movements of the upper extremities exposing workers to MSDs. (For good quality of preserve around 100 pricks are desired per *aonla* fruit and there were only 5-6 needles per hand tool, so the workers have to carry out the same task 18-20 times in single fruit, thus making the task highly repetitive.)

**With fork and hand tool**

**For right hand:** Working with both fork and hand tool involved flexion and abduction of upper and lower arm, highly repetitive motion of wrist joint (40-50 times per minute) along with radial deviation of the wrist, twisted position of wrist especially pronation and force of magnitude 2.5-3 kg ( measured by load cell) was required to prick the fruit.

Working in such a combination of ergonomic stressors especially so highly repetitive motion of angular (wrist) joint places the workers at a high risk of developing MSDs especially carpel tunnel syndrome (CTS).

**For left hand:** Left hand was used to hold the *aonla* fruit and to rotate it so that it can be properly pricked. Pricking task with the conventional tools involved flexion of both upper and lower left arm but no repetitive motion of left angular joint, however the wrist twist was high. So the working with conventional tools didn't impose so much stress on left hand, however, this need to be changed soon.

Postural analysis of the neck and trunk was also found to be stressful as the work in sitting and squatting postures involved greater flexion of neck and trunk as compared to standing posture. Regarding posture of lower extremities, sitting on the ground with folded legs and squatting posture needs to be eliminated as it exposes workers to LBP (Lower back pain) and LEP (Lower extremity pain). The RULA analysis of fork and hand tools with both right and left hand in different working postures are depicted in table 4.7. The scores are allotted on the observation sheet on the basis of above observations regarding movements of upper and lower extremities, neck and trunk, muscles and force used to carry out the activity. Accordingly, action required was suggested.

**With machine**

**For right hand:** With machine there was no such repetitive motion of wrist joint that could be considered harmful. A force of 1.4-1.8 kg was used to operate the machine. However, use of machine involved high flexion of upper and lower hands which resulted into fatigue. The RULA analysis of machine with right hand in different working postures is depicted in table 4.7.

**For left hand:** For left hand there was only high flexion of upper and lower hands and there was no other stress. Machine pricking did not involve stress on left hand.

**Ovako working posture assessments (OWAS) outcomes**

OWAS scores while working with conventional tools and machine in different working posture also indicated that working postures - sitting, squatting and standing should be changed. The results are depicted in table 4.9 and scores are allotted using observation sheet on the basis of position of various body parts like back, upper and lower limb and load experienced during the pricking task. The action list thus generated is presented in table 4.9.

**Spinal angle deviation while working with different tools in various postures**

The normal angle of spine of the workers was found to be $182.6^0$. Data given in table 4.9 reveal that the angle of spine while working with fork was found to be maximum in squatting posture ($196^0$), followed by sitting posture ($192^0$) and least in standing posture ($189^0$). With hand tool also, the spinal deviation was found to be maximum in squatting posture ($195^0$), followed by sitting posture ($190^0$) and least in standing posture ($189^0$). Whereas, with the machine, the spinal deviation was highest in sitting posture ($191^0$), followed by squatting posture ($189^0$) and least in standing posture ($188^0$).

**Table 4.7: RULA analysis with different tools in various postures**

**(n=15)**

| **Treatments** | **Posture** | **Posture score A (Upper arm+lower arm+wrist+wrist twist)** | **Muscle used+ Force** | **Score A** | **Posture score B (Neck, trunk and leg score)** | **Muscle used+ Force** | **Score B** | **Final score** | **Action category** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Conventional tools (right hand)** | **Sitting** | 3+3+4+2=5 | 1+2 | 8 | 3+2+1=3 | 1+2 | 6 | 7 | 4 | **Investigation and changes required immediately** |
| | **Squatting** | 3+3+4+2=5 | 1+2 | 8 | 3+2+2=4 | 1+2 | 7 | 7 | 4 | |
| | **Standing** | 3+3+4+2=5 | 1+2 | 8 | 2+2+1=2 | 1+2 | 5 | 7 | 4 | |
| | | | | | | | | | | |
| **Conventional tools (left hand)** | **Sitting** | 3+3+3+2=5 | 1+0 | 6 | 3+2+1=3 | 1+0 | 4 | 6 | 3 | **Investigation and changes required immediately** |
| | **Squatting** | 3+3+3+2=5 | 1+0 | 6 | 3+2+2=4 | 1+0 | 4 | 6 | 3 | |
| | **Standing** | 3+3+3+2=5 | 1+0 | 6 | 2+2+1=2 | 1+0 | 4 | 6 | 3 | |
| | | | | | | | | | | |
| **Machine (right hand)** | **Sitting** | 4+3+2+2=5 | 1+2 | 8 | 3+2+1=3 | 1+2 | 6 | 7 | 4 | **Investigation and changes required immediately** |
| | **Squatting** | 4+3+2+2=5 | 1+2 | 8 | 3+2+2=4 | 1+2 | 7 | 7 | 4 | |
| | **Standing** | 4+3+2+2=5 | 1+2 | 8 | 2+2+1=2 | 1+2 | 5 | 7 | 4 | |

1* Posture is acceptable if it is not maintained or repeated for long time
2*Further investigation is needed and change may be required
3* Investigation and changes are required soon
4*Investigation and changes are required immediately

**Table 4.8: OWAS analysis with different tools in various postures**

**(n=15)**

| Tools | Posture | Back | Upper limb | Lower limb | Load | Action Category* | |
|---|---|---|---|---|---|---|---|
| **Conventional Tools** | **Sitting** | 2 (bent) | 1(both below shoulder level) | 1 (sitting posture) | 1 | **2** | **Changes should be considered in future planning** |
| | **Squatting** | 2 (bent) | 1(both below shoulder level) | 6 (sitting on both legs) | 1 | **2** | |
| | **Standing** | 2 (bent) | 1(both below shoulder level) | 2(straight standing) | 1 | **2** | |
| | | | | | | | |
| **Machine** | **Sitting** | 2 (bent) | 2(one above shoulder level) | 1 (sitting posture) | 1 | **2** | **Changes should be considered in future planning** |
| | **Squatting** | 2 (bent) | 1(both below shoulder level) | 6 (sitting on both legs) | 1 | **2** | |
| | **Standing** | 2 (bent) | 1(both below shoulder level) | 2(straight standing) | 1 | **2** | |

1*No action are needed to change work posture, 2*changes should be considered in future planning, 3*working method involved should be changed as soon as possible, 4*Immediate solutions should be found to change these posture

**Table 4.9: Spinal angle deviation while using all the tools in different postures**

**(n=15)**

| | **Fork** | | | **Hand tool** | | | **Machine** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Angle** | **Sitting** | **Squatting** | **Standing** | **Sitting** | **Squatting** | **Standing** | **Sitting** | **Squatting** | **Standing** |
| **At normal** (degree) | 182.6±3.7 | | | | | | | | |
| **At working** (degree) | 192.4±4.9 | 196.0±4.2 | 189.0±3.5 | 190.0±4.5 | 195.0±3.9 | 189.0±3.1 | 191.0±4.0 | 189.0±3.9 | 188.0±2.6 |
| **Increase over base** | 9.8 | 13.4 | 6.4 | 7.4 | 12.4 | 6.4 | 8.4 | 6.4 | 5.4 |
| **% increase** | 5.3 | 7.3 | 3.5 | 4.0 | 6.7 | 3.5 | 4.6 | 3.5 | 2.9 |

#### 4.2.1.3 Psycho-physical responses of the workers while working with conventional and improved methods

Psycho-physical responses of the workers while *aonla* pricking were assessed using RPE, VAD score, BPDS and NMQ outcomes. The results are presented in table 4.10-4.12 and fig 4.7-4.9.

**Rating of perceived exertion (RPE) experienced by the workers**

RPE is one of the most reliable tool for the subjective assessment of the exertion. Table 4.10 highlights that while working with fork, RPE was found to be highest in squatting posture (2.7), followed by standing posture (2.4) and least in sitting posture (2.2). Similarly with hand tool RPE was observed to be highest in squatting posture (2.6), followed by standing posture (2.2) and least in sitting posture (2.0). The pattern of RPE experienced by the workers while pricking with hand tool was same as that of the fork. Whereas, while pricking with machine, RPE was found to be maximum in squatting posture (2.4), followed by sitting posture (2.3) and least in standing posture (2.2). The RPE was found to be highest in squatting posture with all the three tools.

**Table 4.10: RPE experienced by workers while pricking task using conventional tools and machine (n=15)**

| Treatments | Rating of perceived exertion score | | |
|---|---|---|---|
| | Sitting | Squatting | Standing |
| **Fork** | 2.2±0.5 | 2.7±0.4 | 2.4±0.4 |
| **Hand tool** | 2.0±0.5 | 2.6±0.4 | 2.2±0.4 |
| **Machine** | 2.3±0.4 | 2.4±0.6 | 2.2±0.5 |

**Visual analogue discomfort (VAD) experienced by the workers**

Table 4.11 reveals that with VAD was highest with fork in squatting posture (7.0) followed by standing posture (6.8) and least in sitting posture (6.6). Similarly, while working with hand tool VAD was highest in squatting posture (7.0) followed by standing posture (6.6) and least in sitting posture (6.5). Whereas, with machine, the VAD experienced was found to be maximum in squatting posture (7.3), followed by sitting posture (7.0) and least in standing posture (6.8). The VAD results were same as that of RPE.

**Table 4.11: VAD experienced by workers in pricking using conventional tools and machine (n=15)**

| Treatments | Visual analogue discomfort score | | |
|---|---|---|---|
| | Sitting | Squatting | Standing |
| **Fork** | 6.6±0.5 | 7.0±0.3 | 6.8±0.4 |
| **Hand tool** | 6.5±0.7 | 7.0±0.4 | 6.6±0.5 |
| **Machine** | 7.0±0.6 | 7.3±0.5 | 6.8±0.5 |

**Body part discomfort (BPDS) experienced by workers**

Table 4.12 illustrates that while working with fork and hand tool, body part discomfort score was found to be maximum in squatting posture (57.6, 56.8), followed by standing posture (48.0, 46.9) and least in sitting posture (40.5, 38.6) respectively. Whereas in pricking with machine, BPDS was found to be maximum in sitting posture (53.9), followed by squatting posture (41.0) and least was observed in standing posture (36.1).

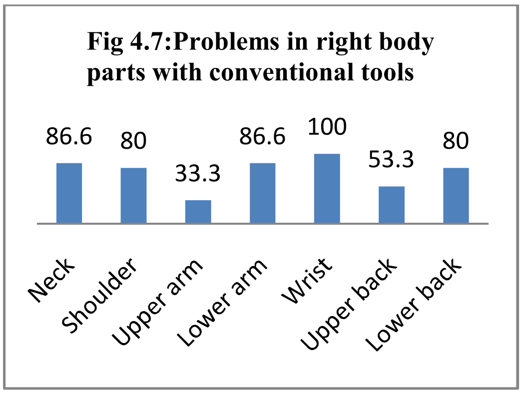
**Table 4.12: Body part discomfort Score for pricking task using conventional tools and machine (n=15)**

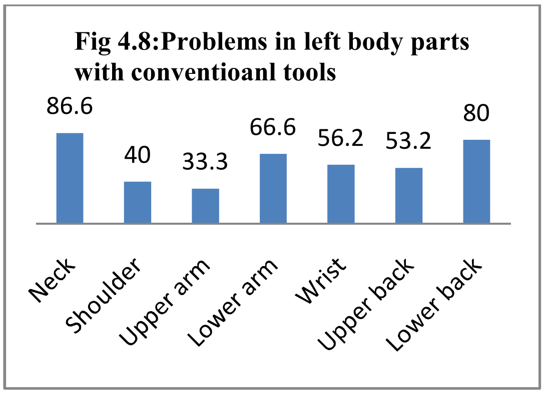
| Treatments | Body part discomfort score | | |
|---|---|---|---|
| | Sitting | Squatting | Standing |
| **Fork** | 40.5±4.0 | 57.6±4.3 | 48±3.3 |
| **Hand tool** | 38.6±5.6 | 56.8±3.3 | 46.9±3.6 |
| **Machine** | 53.9±2.8 | 41.0±2.5 | 36.1±2.1 |

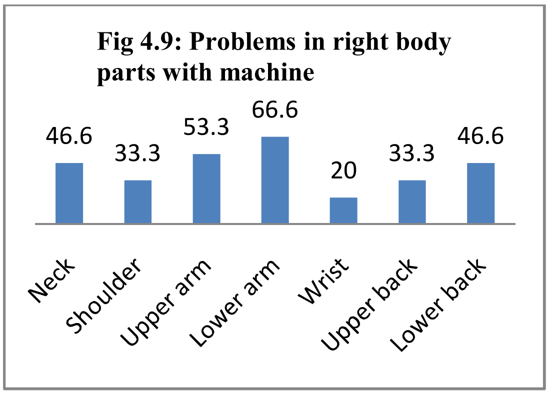
**Outcomes of Nordic musculoskeletal questionnaire (NMQ)**

It is clear from fig 4.7 and 4.8 that pricking workers reported MSDs in different involved body parts like neck, lower and upper back because of working posture and in upper extremities because of highly repetitive nature of the task. The magnitude of musculoskeletal problems differs in right and left upper extremities with problems more severe in right side. The discomfort was found be more severe in right wrist attributed to rapid back and forth movement of wrist joint. 100 percent respondents reported discomfort in wrist after the pricking activity. Nearly, 86.6 percent reported discomfort in lower arm and neck as for the pricking work the lower arm had to be continuously flexed and neck had to be continuously bent. Nearly, 80 percent reported discomfort in shoulder and back as pricking task involve slight jolting action on shoulder and flexion of lower back. However, discomfort was not so severe in left body parts as nearly two third of workers (66.6 %) workers reported pain in lower arm and nearly 56.2 percent reported pain in the wrist joint. Whereas, machine pricking involved greater flexion of the upper and lower arm, thus more workers compared of discomfort in lower (66.6 %) and upper arms (53.3 %). Working with machine didn't cause severe discomfort in involved body parts as it is clear from fig 4.9 that the discomfort experienced by workers in different body parts was 46.6 % percent in neck and lower back each, followed by shoulders and upper back (33.3 %) and in wrist (20 %) was reported very low.

**Musculoskeletal analysis of pricking activity**




### 4.2.2 Acceptability and economic benefits of machine

Acceptability and economic benefits associated with the use of hand operated *aonla* pricking machine have been discussed under following subheads:

**User's acceptability of *aonla* pricking machine**

The user's acceptability of the *aonla* pricking machine was evaluated on the basis of four parameters: relative advantage with the use of machine, compatibility of the machine with workers, simplicity of the machine and satisfaction obtained from the use of machine illustrated in fig 4.10-4.12. Workers felt that machine was time saving (93.3 %), reduces drudgery (86.6 %), was advantageous (83.3 %), labour saving as well as more work could be done with machine (76.6 %) and was affordable (70 %). Regarding compatibility with the use of machine majority of the workers (93.3 %) felt that there was no problem in storage of machine and machine could easily be used (76.6 %), however few workers (23.3 %) also reported that machine doesn't suit to their requirements. Cent percent workers reported that machine was simple equipment and 90 percent felt that it was easy to operate, however 10 percent workers reported that it was difficult for them to keep the machine clean. Majority of workers (77.7 %) were satisfied with the working of machine. All the workers assured that they would pass on the information regarding machine to other *aonla* preserve making enterprises and believed that machine was very useful as income generating tool and the quality of the preserve prepared from machine pricked *aonla* was very good as compared to preserve prepared from hand tool pricked *aonla*.

**Fig 4.10: Relative advantage with use of machine**

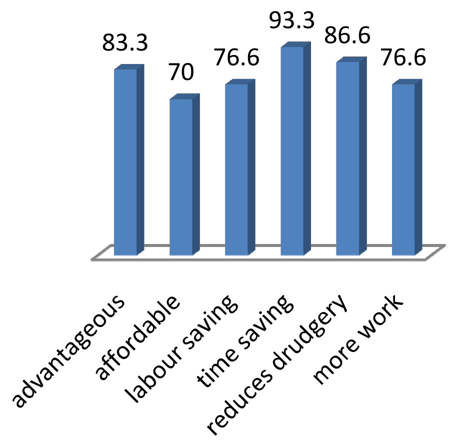



**Fig 4.11: Compatibility with use of machine**

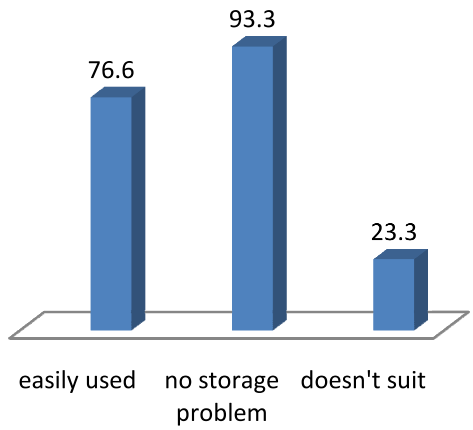
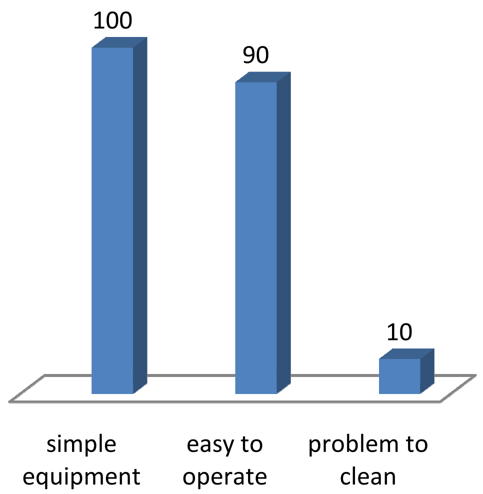



**Fig 4.12: Simplicity of machine**




Safety and comfort associated with the use of *aonla* pricking machine

Further, cent percent of the workers reported that there were no finger injuries, eye aches while working with machine and were comfortable while working on machine However, due to lack of proper workstation, they were facing low to moderate postural stress.

**Economic benefits associated with use of *aonla* pricking machine**

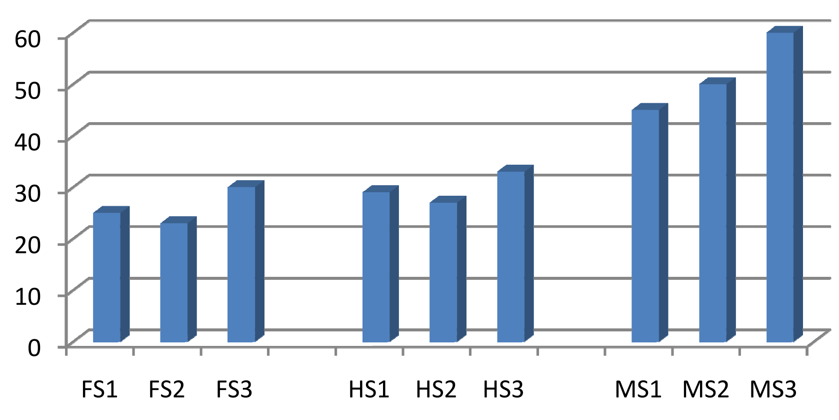
**Output:** Output means number of *aonla* fruit pricked in 20 minutes and is depicted in fig. 4.13. As it is clear from the figure that with use of machine workers were able to prick twice the amount of *aonla* as compared to fork and hand tool. With fork as well as hand tool, the pricking capacity was maximum in standing posture (28-32 number of *aonla*/20 min), followed by sitting posture (25-28 number of *aonla*/20 min) and least in squatting posture

(20-25 number of *aonla*/20 min). Whereas, with machine the pricking capacity of the workers was maximum in standing posture (55-60 number of *aonla*/20 min), followed by squatting posture (45-50 number of *aonla*/20 min) and least in sitting posture (42-45 number of *aonla*/20 min). With the hand tools in the morning hour workers were able to prick 5-6 kg/hr and this capacity reduced to 2-3 kg/hr in evening hours because workers were developing fatigue with time. However, with machine the pricking capacity of the workers remained same throughout the day.

**Quality of pricking**: As per the total sensory score, ascorbic acid and water activity data obtained by different samples under different treatments it was found that the machine pricked *aonla* preserve obtained maximum sensory score, ascorbic acid retention and minimum water activity which is an indication of good acceptability among consumers and good shelf life of the preserve. These parameters are further discussed in next subhead.

The results given above interprets that with the use of machine, workers in a given time were able to prick twice the amount of *aonla* as compared to conventional tools. Twenty minutes pricking with conventional tool was yielding the same output as ten minutes of pricking with machine. With conventional tools, in twenty minutes workers were able to prick around two kg fruits while with machine they were able to prick around four kg in twenty minutes, hence there was saving of ten minutes per two kg of fruits. Consequently, saving in time spent on pricking with machine lead to saving of human energy as well as cost of pricking.

**Fig 4.13: Number of aonla pricked under different treatments**




F (Fork), H (Hand tool), M (Machine)
S1 (Sitting on ground), S2 (Squatting), S3 (Standing)

### 4.3.2 Analysis of organoleptic quality, vitamin C content and water activity of the preserve

*Aonla* preserve was prepared from *aonla* fruits pricked under different treatments and their organoleptic quality, vitamin C content and water activity were analyzed as depicted in fig 14-16.

**Total sensory score of preserve prepared under different treatments**

The sensory of the prepared preserves under different treatments was judged in terms of color and appearance, texture and flavor. The preserve prepared from machine pricked *aonla* obtained maximum sensory score (8.5/10) followed by preserve prepared from hand tool pricked *aonla* (8/10) and least by fork pricked *aonla* (7.5/10). However, a little difference was observed in the sensory scores among preserves prepared under different treatments (fig 4.14)

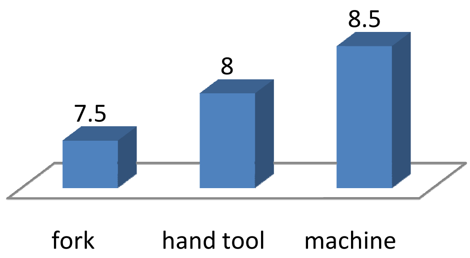



**Fig 4.14: Sensory score of preserves prepared under different treatments**

**Ascorbic acid retention of preserve prepared under different treatments**

As it is clear from figure 4.15 that maximum ascorbic acid content was found in machine pricked preserve (150 mg/100 gm preserve), followed by fork pricked preserve (95 mg/100 gm preserve) and least in hand tool pricked preserve (90 mg/100 gm preserve).

**Water activity of preserve prepared under different treatments**

The water activity was found least in case of machine pricked preserve (0.53) and highest in fork pricked preserve (0.56) as attributed to the quality of pricking by different treatments. However, a little difference was observed in the obtained values of water activity as presented in Fig 4.16.

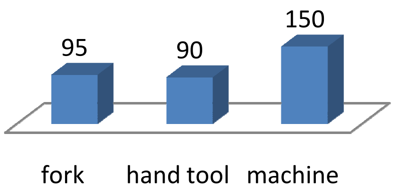



**Fig 4.15: Vitamin C content of preserves prepared under different treatments**

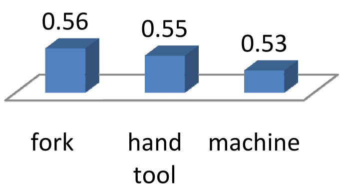



**Fig 4.16: Water activity of preseves prepared under different treatments**

### 4.3 Development of workstation, optimization of process parameters using RSM and application of WISE methodology

### 4.3.1 Development of prototype workstation

The anthropometric dimensions of the 30 workers of phase were taken to develop the prototype workstation (table 4.13). Standing and sitting measurements, hand and arm measurements and normal and maximum reaches of all the workers were taken and then mean, standard deviation, 5th and 95th percentile values were calculated.

**Table 4.13: Anthropometric dimensions of *aonla* pricking workers (n=30)**

| S. No. | Body parts | Mean | SD | 5th percentile | 95th percentile |
|---|---|---|---|---|---|
| **Standing anthropometric measurements (cm)** | | | | | |
| 1 | Weight | 50.6 | 4.6 | 42.9 | 58.3 |
| 2 | Height | 157.6 | 4.7 | 149.8 | 165.4 |
| 3 | Elbow height | 98.4 | 4.2 | 91.5 | 105.3 |
| **Sitting anthropometric measurements (cm)** | | | | | |
| 1 | Sitting height | | | | |
| | Normal | 76.1 | 2.6 | 71.7 | 80.5 |
| | Erect | 81.0 | 3.2 | 75.7 | 86.3 |
| 2 | Hip breadth | 38.4 | 2.4 | 34.3 | 42.4 |
| 3 | Knee height | 51.0 | 2.7 | 46.4 | 55.5 |
| 4 | Popliteal height | 44.5 | 2.1 | 40.9 | 48.1 |
| 5 | Buttock -popliteal length | 46.2 | 3.3 | 40.6 | 51.7 |
| 6 | Buttock- knee length | 52.8 | 3.0 | 47.8 | 57.9 |
| **Hand and Arm anthropometric measurements (cm)** | | | | | |
| 1 | Hand breadth | 7.3 | 0.4 | 6.6 | 8.1 |
| 2 | Hand breadth across thumb | 9.3 | 0.3 | 8.7 | 9.9 |
| 3 | Hand length | 16.6 | 1.1 | 14.8 | 18.5 |
| 4 | Arm length | 70.9 | 3.6 | 64.8 | 76.9 |
| | Upper arm | 29.3 | 2.3 | 25.5 | 33.1 |
| | Lower arm | 41.5 | 2.1 | 38.0 | 45.0 |
| **Normal and Maximum Reaches** | | | | | |
| 1 | Normal reach in horizontal plane | | | | |
| | Right hand | 66.2 | 4.9 | 58.1 | 74.4 |
| | Left hand | 64.1 | 5.1 | 55.6 | 72.6 |
| 2 | Maximum Reach in Horizontal plane | | | | |
| | Right hand | 72.1 | 5.2 | 63.6 | 80.7 |
| | Left hand | 68.4 | 5.4 | 59.4 | 77.4 |

The weight, height and elbow height of the workers was found to be 50.6 kg, 157.6 cm and 98.4 cm respectively. Regarding measurements in sitting posture for designing a suitable working chair, sitting height (normal 76.1 cm and erect 81.0 cm), hip breadth (38.4 cm), knee height (51.0 cm), popliteal height (44.5 cm), buttock-popliteal length (46.2 cm) and buttock-knee length (52.8 cm) were measured. For determining the location of the machine on the workstation and size of handle of machine, hand breadth (5.3 cm), hand breadth across thumb (9.3 cm), hand length (16.6 cm) and arm length (both upper arm 29.3 cm and lower arm 41.5 cm) were measured. For determining the location of various tools and supplies within the workstation platform, normal and maximum reaches of workers with both the hands in horizontal plane were measured. The normal reaches in the horizontal plane with right hand and left hand were found out to be 66.2 cm and 64.1 cm respectively, whereas the maximum reaches with right hand and left hand were found out to be 72.1 cm and 68.4 cm respectively.

### 4.3.2 Optimization of the process parameters using Response surface methodology (RSM)

Optimization of the process parameters aimed at finding the level of intermediate variables viz. height of workstation, light at workstation and time spent on workstation where pricking would be done at minimum HR, BPDS and at the same time would result into maximum productivity in terms of number of *aonla* fruit pricked and total sensory evaluation of the prepared preserve. The RSM was applied on all the three tools *i.e.* fork, hand tool and machine and a total of 17 experiments were carried out for each tool. The design layouts with results are presented from the table 4.14-4.25 and fig 4.15-4.39.

The response surface or contour plots were generated for different interaction of any two independent variables, while keeping the third variable constant. Such three dimensional surfaces give accurate representation and provide useful information about the behavior of the system within the experiment design.

**RSM analysis for fork**

For conducting RSM analysis of fork, the process parameters selected along with their range were posture (sitting on low stool 200 mm, sitting on chair 600 mm and standing 1000 mm), light (100 lux, 300 lux, 500 lux) and time (1 hr, 2 hr and 3 hr). The responses selected were heart rate, body part discomfort score, productivity and total sensory score. Table 4.14 depicts a set of 17 experiments showing different combinations of process parameters along with responses.

**Checking of fitting mode for various responses**

The statistical analysis of the experimental data was performed to observe the effect of various process parameters on measured responses and to obtain predicted equations for different responses (table 4.14 and 4.15). The results indicate the adequacy of quadratic model for HR, productivity and sensory and linear model for BPDS. The relative effect of each process parameter on individual response was compared from the p-value less than 0.05 indicate model terms are significant.

The model F-value of 55.6, 81.4, 168.6 and 58.0 for HR, BPDS, productivity and sensory respectively indicated that model was significant thus assuring towards aappropriatness of the results obatined in 17 combinations of process parameters and responses. Values of $p<0.05$ indicate that model terms were significant. In case of HR, A, C, AC and $A^2$ were significant terms indicating that they were affecting the HR most. In case of BPDS, A, B, C, $A^2$ , $B^2$ and $C^2$ were significant term indicating that they were affecting the BPDS most. In case of productivity C, $A^2$, $B^2$ and $C^2$ were significant terms and in case of sensoryA, B, C and $A^2$ were significant terms (Table 4.15).

**Table 4.14: Experimental design and experimental data for optimization process**

| **RUNS** | **Coded process variables** | | | **Responses** | | | |
|---|---|---|---|---|---|---|---|
| | **Height (mm)** | **Light (lux)** | **Time (hr)** | **HR (beats.min$^{-1}$)** | **BPDS** | **Productivity (Kg/h)** | **Sensory Score** |
| 1 | 200 | 100 | 2 | 87 | 80 | 11.0 | 7.8 |
| 2 | 1000 | 100 | 2 | 94 | 85 | 10.0 | 7.2 |
| 3 | 200 | 500 | 2 | 86 | 77 | 11.2 | 8.2 |
| 4 | 1000 | 500 | 2 | 94 | 83 | 10.5 | 7.5 |
| 5 | 200 | 300 | 1 | 82 | 69 | 6.0 | 8.5 |
| 6 | 1000 | 300 | 1 | 87 | 72 | 6.0 | 8.2 |
| 7 | 200 | 300 | 3 | 90 | 88 | 15.0 | 7.2 |
| 8 | 1000 | 300 | 3 | 103 | 97 | 14.5 | 7.0 |
| 9 | 600 | 100 | 1 | 82 | 62 | 7.0 | 8.5 |
| 10 | 600 | 500 | 1 | 81 | 60 | 7.2 | 8.8 |
| 11 | 600 | 100 | 3 | 88 | 83 | 15.0 | 7.2 |
| 12 | 600 | 500 | 3 | 87 | 79 | 16.0 | 7.8 |
| 13 | 600 | 300 | 2 | 84 | 75 | 13.0 | 8.0 |
| 14 | 600 | 300 | 2 | 86 | 77 | 14.0 | 7.8 |
| 15 | 600 | 300 | 2 | 84 | 72 | 13.0 | 8.1 |
| 16 | 600 | 300 | 2 | 86 | 75 | 14.0 | 7.9 |
| 17 | 600 | 300 | 2 | 86 | 77 | 13.0 | 8.0 |

**Table 4.15: Analysis of variance (ANOVA) for different response models for fork**

| Source[a] | HR | BPDS | Productivity | Sensory score |
|---|---|---|---|---|
| **Model fitted** | **Quadratic** | **Quadratic** | **Quadratic** | **Quadratic** |
| **F value** | | | | |
| **Model** | 55.60*** | 81.42*** | 168.65*** | 58.08*** |
| **A(height)** | 70.32** | 29.32** | 3.69ns | 23.84** |
| **B(light)** | ns | 6.71** | 2.91ns | 18.83** |
| **C(time)** | 81.73** | 391.03** | 854.65** | 169.50** |
| **AB(height-light)** | ns | ns | ns | ns |
| **AC(height-time)** | 6.75** | 3.99ns | ns | ns |
| **BC(light-time)** | ns | ns | ns | Ns |
| **$A^2$ ($height^2$)** | 63.77** | 127.83** | 81.74** | 24.13** |
| **B2($light^2$)** | ns | 9.24** | 19.33** | ns |
| **$C^2$($time^2$)** | ns | 7.28** | 535.34** | ns |
| **Lack of fit** | 2.10ns | 0.17ns | 0.29ns | 1.48ns |
| **$R^2$** | 0.948 | 0.984 | 0.990 | 0.952 |
| **Adjusted $R^2$** | 0.932 | 0.972 | 0.984 | 0.936 |
| **Predicted $R^2$** | 0.823 | 0.959 | 0.977 | 0.897 |

***significant at $p<0.001$, **significant at $p<0.05$
NS= Not significant
[a] A= height, B= light, C= time

The following predicted equations were obtained for all the individual variables and interactions among the variables.

**Table 4.16: Predicted equations for different responses for fork**

| Responses | Predicted equations for the responses in terms of coded factors[a] | $R^2$ |
|---|---|---|
| **HR** | $9.24+0.22A+0.24C+0.088AC+0.28A^2$ | 0.948 |
| **BPDS** | $75.20+2.88A-1.38B+10.50C+8.28A^2-2.23B^2-1.97C^2$ | 0.984 |
| **Productivity** | $13.40-0.28A+0.25B+4.28C-1.82A^2-0.89B^2-1.20C^2$ | 0.990 |
| **Sensory score** | $8.01-0.22A+0.20B-0.60C-0.31A^2$ | 0.952 |

[a] A= height, B= light, C= time

**Interaction among variables and responses**

Figures 4.17-4.24 were obtained showing relationship of any 2 intermediate variables with any one dependent variable.

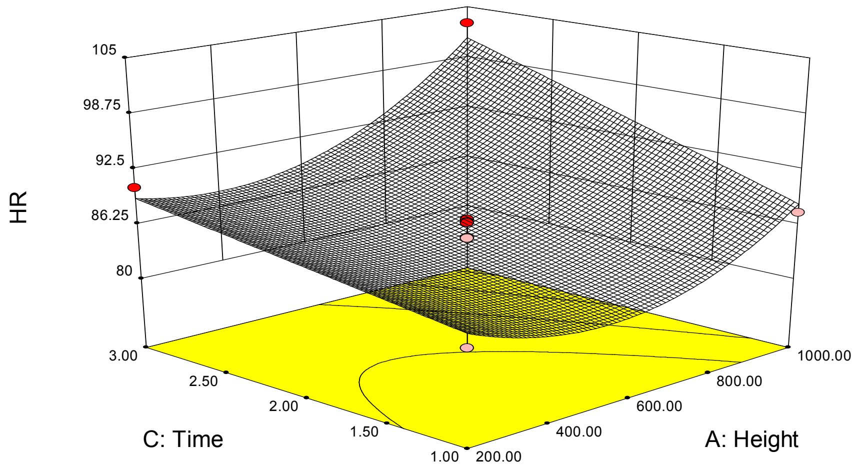



**Fig 4.17: Effect of time and height on heart rate**

Figure 4.17 depicts the interaction among time, height and HR. It is clear from the figure that HR while working with fork was found to be minimum in sitting posture and on moving either to low stool posture or standing posture HR increased. Whereas, with time, HR was showing a continuous increase.

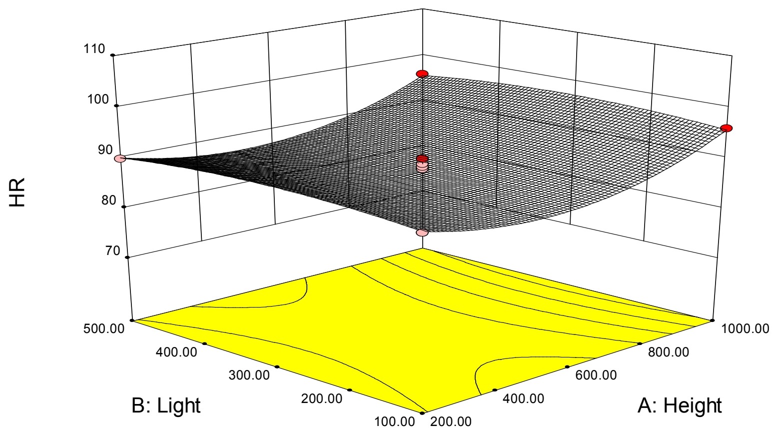



**Fig 4.18: Effect of light and height on heart rate**

Figure 4.18 depicts the interaction among light, height and HR. It is clear from the figure that HR while working with fork was found to be minimum in sitting posture and on moving either to low stool posture or standing posture HR increased. Whereas, light has shown no effect on HR.

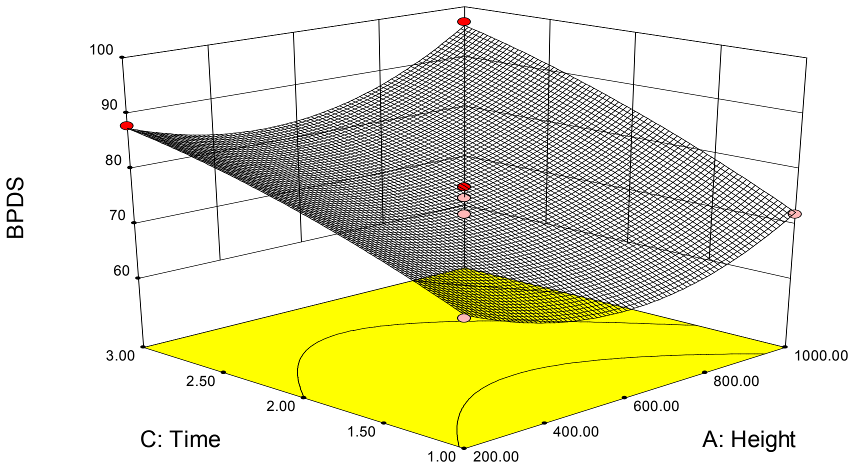



**Fig 4.19: Effect of time and height on body part discomfort score**

Fig 4.19 depicts interaction among time, height and body part discomfort score. BPDS was found to be minimum in sitting posture and increased on moving to either sides of sitting posture. Whereas, with time BPDS was showing a continuous increase.

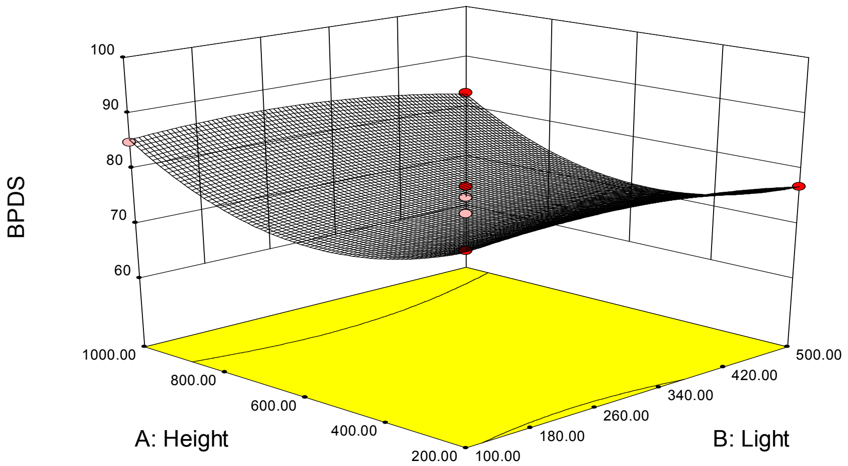



**Fig 4.20: Effect of height and light on body part discomfort score**

Fig 4.20 is showing among between height, light and BPDS. The BPDS was found to be minimum in sitting height and increased on moving to either sides of sitting height. Whereas, light has negligible effect on BPDS.

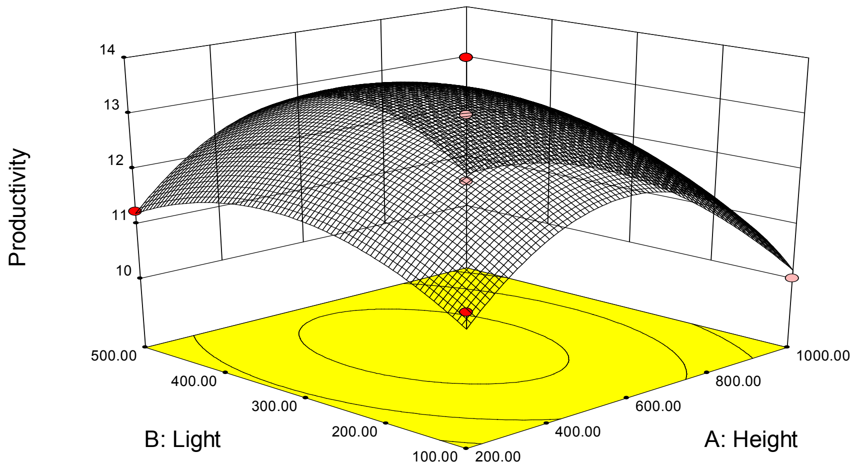



**Fig 4.21: Effect of light and height on productivity**

Fig 4.21 is showing interaction among light, height and productivity. Productivity was found to be maximum at sitting posture and at light intensity of 300-400 lux.

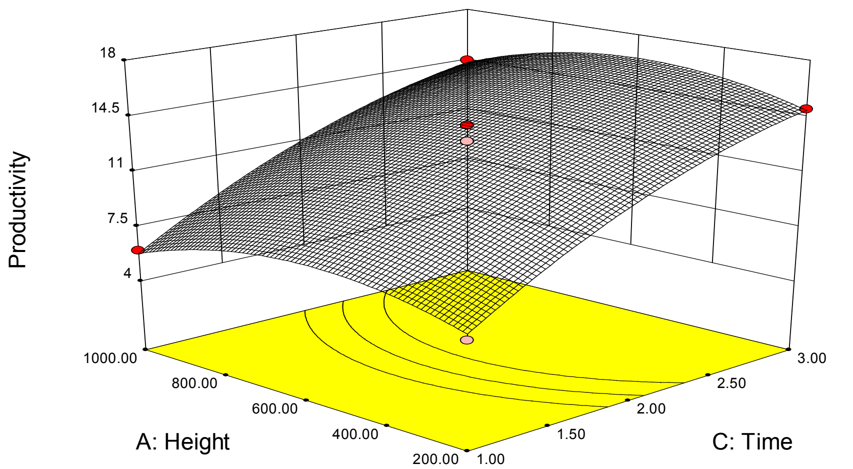



**Fig 4.22: Effect of height and time on productivity**

Fig 4.22 is showing interaction among height, time and productivity. Productivity was found to be maximum at sitting height and was constantly increasing with time.

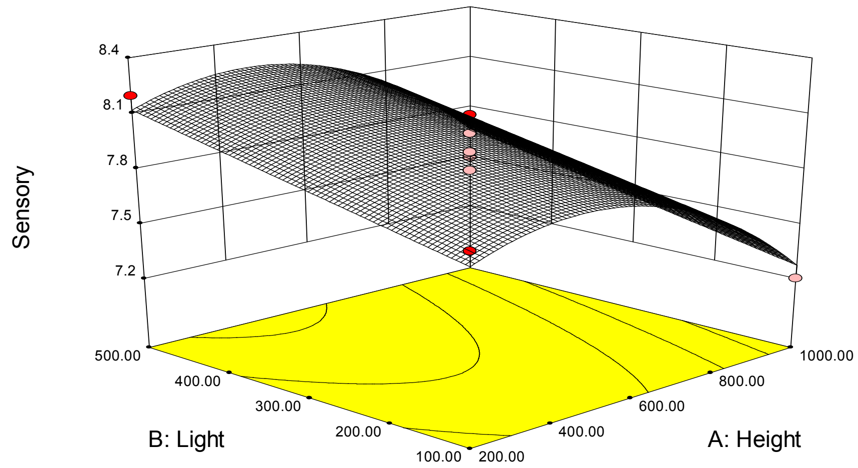



**Fig 4.23: Effect of light and height on sensory score**

Fig 4.23 depicts the interaction among light, height and sensory score. Preserve prepared from *aonla* fruits pricked at sitting height and pricked around 500 lux light obtained maximum sensory score.

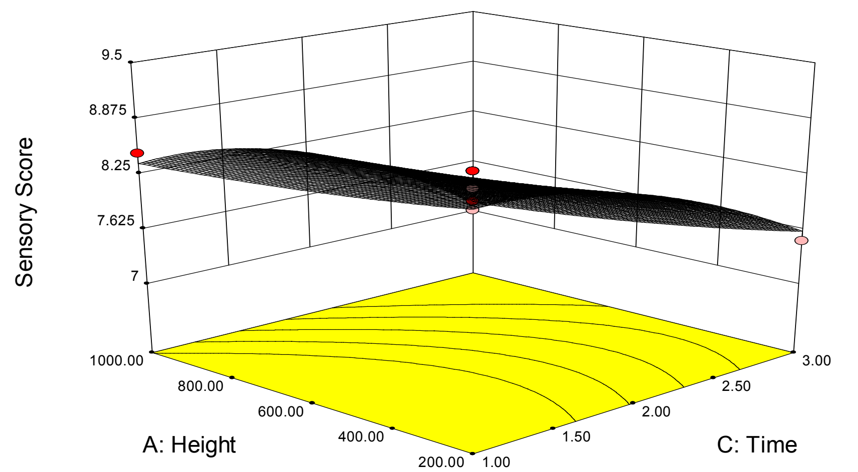



**Fig 4.24: Effect of height and time on sensory score**

Fig 4.24 depicts the interaction among light, time and sensory score. Preserve prepared from *aonla* fruits pricked at sitting height obtained maximum sensory score. With time, sensory score was continuously decreasing.

**Optimization of parameters**

The optimum condition for each process variable along with the predicted values of responses and overall desirability are given in table 4.17. The best optimized conditions obtained while working with fork were working by sitting at 500 mm high chair at light intensity of around 500 lux for 2 hr. Working in this combination would result into minimum increase in HR and BPDS while pricking task and maximum increase in productivity along with good quality pricking.

**Table 4.17: Optimization of parameters**

| Solutions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **S. No.** | **Height** (mm) | **Light** (lux) | **Time** (hr) | **HR** ($beats.min^{-1}$) | **BPDS** | **Productivity** (kg/hr) | **Sensory score** | **Desirability** | |
| 1 | 513.14 | 499.99 | 2.02 | 84.86 | 71.57 | 12.82 | 8.233 | 0.734126 | Selected |
| 2 | 513.94 | 499.94 | 2.01 | 84.83 | 71.49 | 12.79 | 8.237 | 0.734123 | |
| 3 | 517.43 | 499.77 | 2.02 | 84.87 | 71.55 | 12.82 | 8.232 | 0.734104 | |

Height: range, Light : range, Time : range, HR : minimum, BPDS:minimum, Productivity: maximum, Sensory: range

**RSM analysis for hand tool**

Table 4.18 depicts the set of 17 process parameters along with responses.

**Table 4.18: Experimental design and experimental data for optimization process**

| RUNS | Coded process variables | | | Responses | | | |
|---|---|---|---|---|---|---|---|
| | **Height** (mm) | **Light** (lux) | **Time** (hr) | **HR** ($beats.min^{-1}$) | **BPDS** | **Productivity** (Kg/h) | **Sensory score** |
| 1 | 200 | 100 | 2 | 86 | 78 | 11.2 | 8 |
| 2 | 1000 | 100 | 2 | 94 | 83 | 10.1 | 7.5 |
| 3 | 200 | 500 | 2 | 86 | 75 | 11.8 | 8.5 |
| 4 | 1000 | 500 | 2 | 94 | 80 | 10.7 | 7.8 |
| 5 | 200 | 300 | 1 | 82 | 67 | 6.5 | 8.8 |
| 6 | 1000 | 300 | 1 | 87 | 70 | 6.1 | 8.5 |
| 7 | 200 | 300 | 3 | 90 | 86 | 15.3 | 7.5 |
| 8 | 1000 | 300 | 3 | 102 | 94 | 14.5 | 7.0 |
| 9 | 600 | 100 | 1 | 81 | 62 | 7.0 | 8.7 |
| 10 | 600 | 500 | 1 | 81 | 60 | 7.5 | 9.0 |
| 11 | 600 | 100 | 3 | 87 | 80 | 15.7 | 7.5 |
| 12 | 600 | 500 | 3 | 88 | 76 | 16.4 | 8.0 |
| 13 | 600 | 300 | 2 | 84 | 72 | 13.3 | 8.3 |
| 14 | 600 | 300 | 2 | 84 | 72 | 14.0 | 8.1 |
| 15 | 600 | 300 | 2 | 84 | 75 | 13.5 | 8.3 |
| 16 | 600 | 300 | 2 | 86 | 71 | 14.0 | 8.1 |
| 17 | 600 | 300 | 2 | 84 | 75 | 13.5 | 8.3 |

**Checking of fitting mode for various responses**

The statistical analysis of the experimental data was performed to observe the effect of various process parameters on measured responses and to obtain predicted equations for different responses (table 4.19 and 4.20). The results indicate the adequacy of quadratic model for HR, BPDS, productivity and sensory. The model F-value of 88.1, 81.4, 526.8 and 79.8 for HR, BPDS, productivity and sensory respectively indicated that model was significant thus assuring towards aappropriatness of the results obatined in 17 combinations of process parameters and responses. Values of $p<0.05$ indicate that model terms were significant. In case of HR, A, C, AC and $A^2$ were significant terms. In case of BPDS, A, B, C and $A^2$ were significant terms. In case of productivity, A, B, C , $A^2$, $B^2$ and $C^2$ were significant terms and in case of sensory, A, B, C and $A^2$ were significat terms. These significant terms indicate that responses were most affected by mentioned process parameters.

**Table 4.19: Analysis of variance (ANOVA) for different response models for hand tool**

| Source[a] | HR | BPDS | Productivity | Sensory score |
|---|---|---|---|---|
| **Model fitted** | **Quadratic** | **Quadratic** | **Quadratic** | **Quadratic** |
| **F value** | | | | |
| **Model** | 88.15*** | 57.75*** | 526.83*** | 79.83*** |
| **A(height)** | 103.11** | 17.50** | 25.08** | 35.82** |
| **B(light)** | ns | 5.71** | 12.51** | 20.15** |
| **C(time)** | 135.38** | 235.28** | 2673.05** | 232.93** |
| **AB(height-light)** | ns | ns | ns | ns |
| **AC(height-time)** | 9.10** | ns | ns | ns |
| **BC(light-time)** | ns | ns | ns | ns |
| **$A^2$ (height$^2$)** | 105.00** | 82.89** | 255.16** | 30.43** |
| **B2(light$^2$)** | ns | 4.70ns | 49.96** | ns |
| **$C^2$(time$^2$)** | ns | 3.53ns | 103.93** | ns |
| **Lack of fit** | 2.28ns | 0.83ns | 0.28ns | 1.24ns |
| **$R^2$** | 0.967 | 0.972 | 0.997 | 0.964 |
| **Adjusted $R^2$** | 0.956 | 0.955 | 0.995 | 0.952 |
| **Predicted $R^2$** | 0.878 | 0.918 | 0.993 | 0.925 |

***significant at $p<0.001$, **significant at $p<0.05$
NS= Not significant
[a] A= height, B= light, C= time

The following predicted equations were obtained from all the individual variables and interactions among the variables.

**Table 4.20: Predicted equations for different responses for hand tool**

| Responses | Predicted equations for the responses in terms of coded factors[a] | $R^2$ |
|---|---|---|
| **HR** | $84.74+4.03A+4.62C+1.69AC^2+5.59A^2$ | 0.967 |
| **BPDS** | $73+2.63A-1.50B+9.63C+7.87A^2-1.88B^2-1.62C^2$ | 0.972 |
| **Productivity** | $13.66-0.42A+0.30B+4.35C-1.85A^2-0.82B^2-1.18C^2$ | 0.997 |
| **Sensory** | $8.27-0.25A+0.19B-0.64C-0.32A^2$ | 0.964 |

[a] A= height, B= light, C= time

**Interaction among variables and responses**

Figures 4.25-4.32 were obtained showing relationship of any 2 independent variable with any one dependent variable.

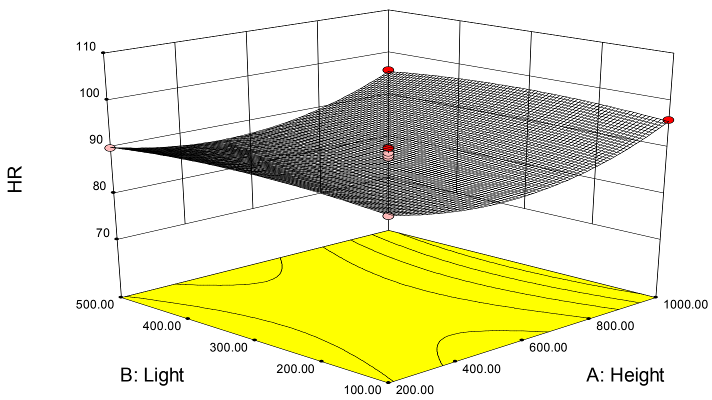



**Fig. 4.25: Effect of light and height on heart rate**

Fig 4.26 depicts the interaction among light, height and heart rate. HR was found to be minimum in sitting posture and light has shown no effect on HR.

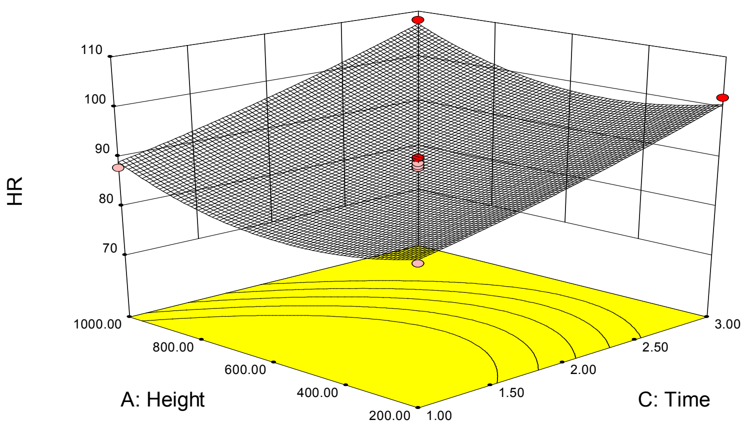



**Fig 4.26: Effect of height and time on heart rate**

Fig 4.26 depicts interaction between height, time and heart rate. The HR was found to be minimum at sitting height and HR was increasing continuously with increase in time.

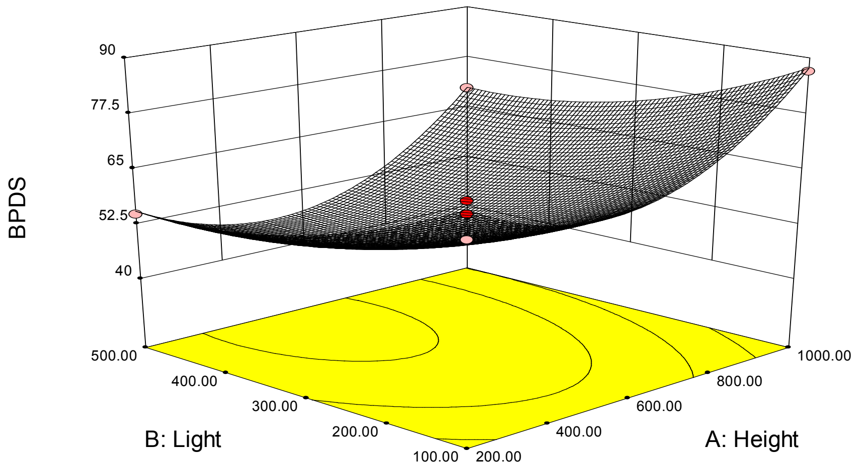



**Fig 4.27: Effect of light and height on body part discomfort score**

Fig 4.27 depicts the interaction between light, height and BPDS. BPDS was found to be minimum near sitting height and light has shown negligible effect on BPDS.

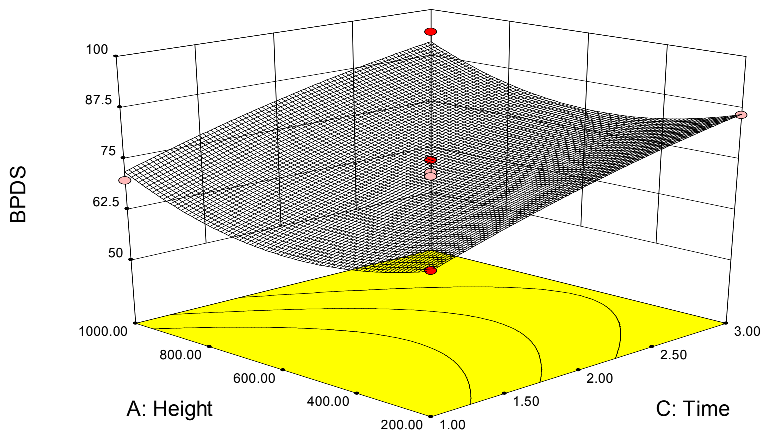



**Fig 4.28: Effect of height and time on body part discomfort score**

Fig 4.28 depicts interaction between height, time and BPDS. BPDS was found to be minimum at sitting height and was continuously increasing with time.

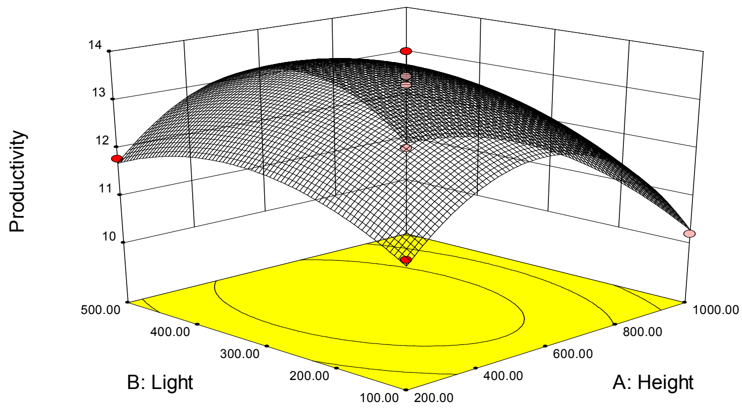



**Fig 4.29: Effect on light and height on productivity**

Fig 4.29 depicts the interaction between light, height and productivity. Productivity was found to be maximum at sitting height near 300-400 lux light.

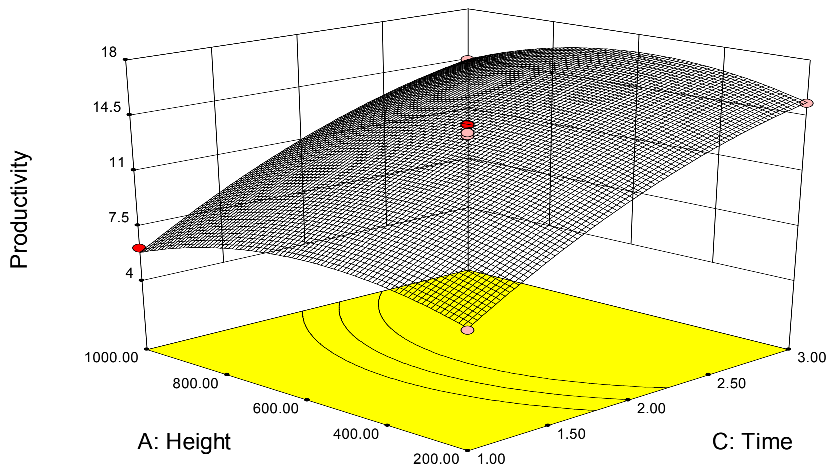



**Fig 4.30: Effect of height and time on productivity**

Fig 4.30 depicts the interaction between height, time and productivity. Productivity was maximum at sitting height and has shown a continuous increase with time.

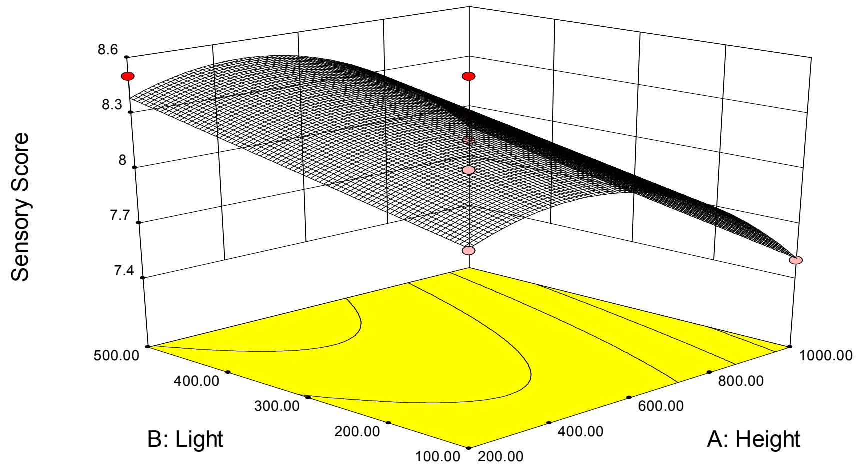



**Fig 4.31: Effect of light and height on sensory score**

Fig 4.31 depicts the relationship among light, height and sensory score. Preserve prepared from *aonla* fruits pricked at sitting height and pricked around 500 lux light obtained maximum sensory score.

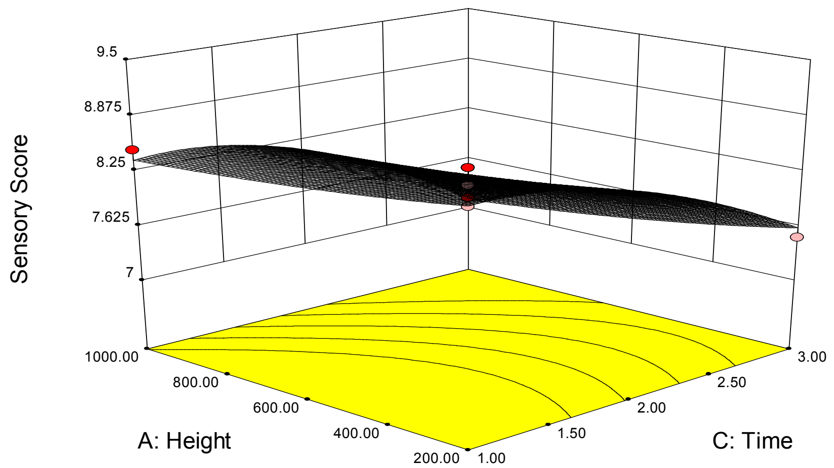



**Fig 4.32: Effect of height and time on sensory score**

Fig 4.32 depicts the interaction among light, time and sensory score. Preserve prepared from *aonla* fruits pricked at sitting height obtained maximum sensory score. With time, sensory score was continuously decreasing.

**Optimization of parameters**

The optimum condition for each process variable along with the predicted values of responses and overall desirability are given in table 4.21. The best optimized conditions obtained were working by sitting at 500 mm high chair at light intensity of around 500 lux for 2 hr. Working in this combination would result into minimum increase in HR and BPDS while pricking task and maximum increase in productivity along with good quality pricking.

**Table 4.21: Optimization of parameters**

| Solutions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **No.** | **Height (mm)** | **Light (lux)** | **Time (hr)** | **HR (beats.min$^{-1}$)** | **BPDS** | **Productivity (kg/hr)** | **Sensory Score** | **Desirability** | |
| 1 | 513.12 | 499.99 | 1.99 | 84 | 69.29 | 13.08 | 8.5022 | 0.747969 | Selected |
| 2 | 516.17 | 499.85 | 2.00 | 84 | 69.43 | 13.15 | 8.4915 | 0.747926 | |

Height: in range, Light : in range, Time : in range, HR : minimum, BPDS:minimum, Productivity: maximum, Sensory: range

**RSM analysis for machine**

Table 4.22 depicts the set of 17 process parameters along with responses outcomes.

**4.22: Experimental design and experimental data for optimization process**

| RUNS | Coded process variables | | | Responses | | | |
|---|---|---|---|---|---|---|---|
| | **Height (mm)** | **Light (lux)** | **Time (hr)** | **HR (beats.min-$^{1}$)** | **BPDS** | **Productivity (Kg/h)** | **Sensory score** |
| 1 | 200 | 100 | 2 | 94 | 47 | 22 | 8.2 |
| 2 | 1000 | 100 | 2 | 100 | 60 | 19 | 8 |
| 3 | 200 | 500 | 2 | 94 | 40 | 22 | 8.3 |
| 4 | 1000 | 500 | 2 | 100 | 60 | 19 | 8.2 |
| 5 | 200 | 300 | 1 | 87 | 34 | 14 | 8.5 |
| 6 | 1000 | 300 | 1 | 92 | 40 | 14 | 8.5 |
| 7 | 200 | 300 | 3 | 102 | 57 | 28 | 7.8 |
| 8 | 1000 | 300 | 3 | 107 | 75 | 25 | 7.8 |
| 9 | 600 | 100 | 1 | 90 | 39 | 11 | 7.6 |
| 10 | 600 | 500 | 1 | 90 | 39 | 11 | 7.6 |
| 11 | 600 | 100 | 3 | 108 | 74 | 22 | 7 |
| 12 | 600 | 500 | 3 | 108 | 74 | 22 | 7.2 |
| 13 | 600 | 300 | 2 | 98 | 50 | 17 | 7.5 |
| 14 | 600 | 300 | 2 | 97 | 47 | 17 | 7.3 |
| 15 | 600 | 300 | 2 | 98 | 49 | 18 | 7.6 |
| 16 | 600 | 300 | 2 | 97 | 48 | 18 | 7.6 |
| 17 | 600 | 300 | 2 | 98 | 45 | 18 | 7.4 |

**Checking of fitting mode for various responses**

The statistical analysis of the experimental data was performed to observe the effect of various process parameters on measured responses and to obtain predicted equations for different responses (table 4.23 and 4.24). The model F-value of 165.5, 71.0, 175.3 and 37.4 for HR, BPDS, productivity and sensory respectively indicated that model was significant thus assuring towards aappropriatness of the results obatined in 17 combinations of process parameters and responses.. Values of $p<0.05$ indicated that model terms were significant. In case of HR, A, C and $A^2$ were significant model terms. In case of BPDS, A, C, AC, $B^2$ and $C^2$ were significant terms. In case of productivity, A, C, AC, $A^2$ and $C^2$ were the most significant terms and in case of sensory B, C and $A^2$ were the most significant terms. These significant terms indicate that responses were most affected by mentioned process parameters.

**4.23: Analysis of variance (ANOVA) for different response models for machine**

| Source[a] | HR | BPDS | Productivity | Sensory score |
|---|---|---|---|---|
| **Model fitted** | **Quadratic** | **Linear** | **Quadratic** | **Quadratic** |
| | **F value** | | | |
| **Model** | 165.51*** | 71.07*** | 175.39*** | 37.42*** |
| **A(height)** | 97.58** | 65.02** | 26.45** | 1.89ns |
| **B(light)** | ns | 0.98ns | ns | 41.26** |
| **C(time)** | 878.23** | 327.89** | 721.38** | 17.05** |
| **AB(height-light)** | ns | ns | ns | ns |
| **AC(height-time)** | ns | 5.76** | 5.88** | ns |
| **BC(light-time)** | ns | ns | ns | ns |
| **$A^2$ (height$^2$)** | 11.48** | ns | 120.31** | 89.47** |
| **B2(light$^2$)** | 3.33ns | 13.37** | ns | ns |
| **$C^2$(time$^2$)** | 3.33ns | 11.91** | 5.36** | ns |
| **Lack of fit** | 2.78ns | 2.15ns | 1.43ns | 1.12ns |
| **$R^2$** | 0.990 | 0.977 | 0.988 | 0.926 |
| **Adjusted $R^2$** | 0.984 | 0.963 | 0.982 | 0.901 |
| **Predicted $R^2$** | 0.964 | 0.902 | 0.946 | 0.842 |

***significant at $p<0.001$, **significant at $p<0.05$
NS= Not significant
[a] A= height, B= light, C= time

The following predicted equations were obtained from all the individual variables and interactions among the variables.

**4.24: Predicted equations for different responses**

| Responses | Predicted equations for the responses in terms of coded factors[a] | $R^2$ |
|---|---|---|
| **HR** | $97.60+2.75A+8.25C-1.30A^2+0.70B^2+0.70C^2$ | 0.990 |
| **BPDS** | $47.5+7.13A-0.87B+16.00C+3.00AC+4.45B^2+4.20C^2$ | 0.977 |
| **Productivity** | $17.42-1.12A+5.58C-0.75AC+3.30A^2-0.70C^2$ | 0.988 |
| **Sensory score** | $7.57-0.075A+0.35B-0.23C+0.71A^2$ | 0.926 |

[a] A= height, B= light, C= time

**Interaction among variables and responses**

Figures 4.33-4.39 were obtained showing relationship of any 2 independent variable with any one dependent variable.

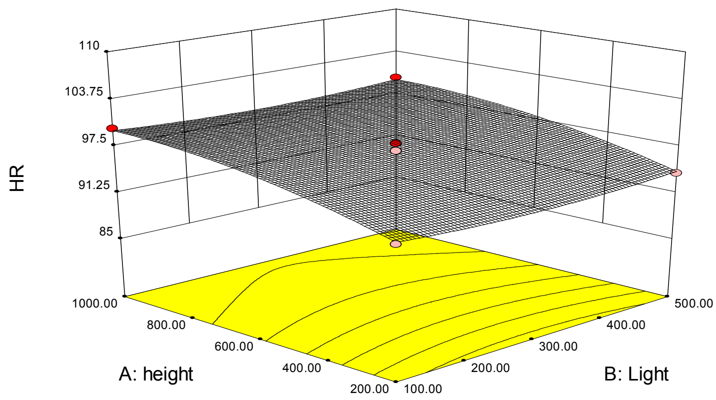



**Fig 4.33: Effect of height and light on heart rate**

Fig 4.33 depicts interaction among height, light and HR while working with machine.HR was found to be slowely incresing with height and light has shown no effect on HR.

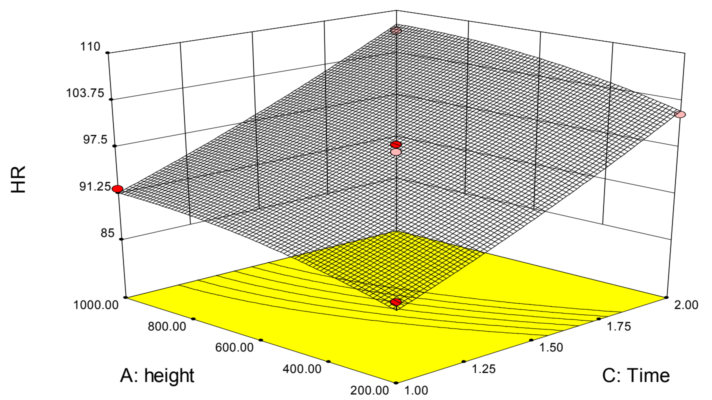



**Fig 4.34: Effect of height and time on heart rate**

Fig 4.34 depicts interaction among height, time and HR while working with machine.HR was found to be slowely incresing with height and HR was continously incresing with time.

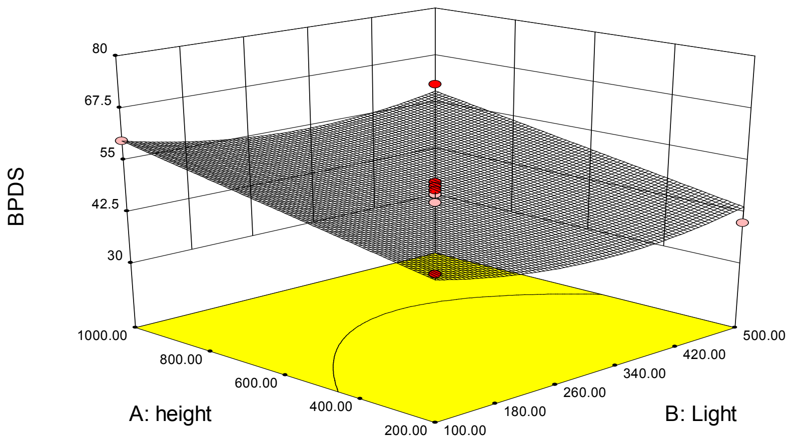



**Fig 4.35: Effect of height and light on body parts discomfort score**

Fig 4.35 depicts interaction among height, light and BPDS. BPDS was found to be incresing with height and light has shown no effect on BPDS.

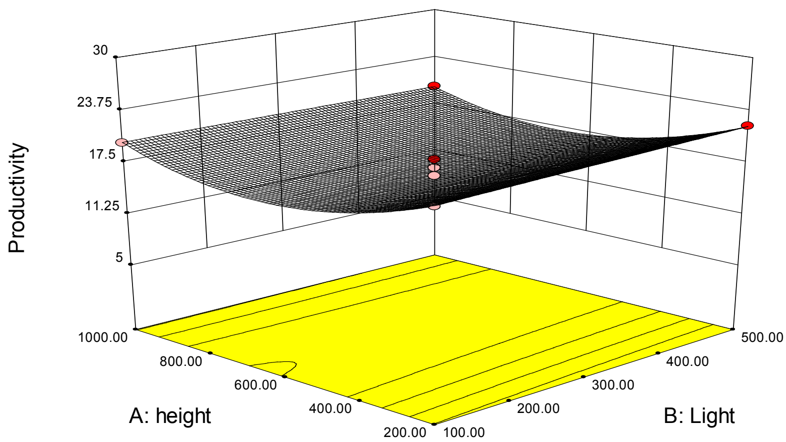



**Fig 4.36: Effect of height and light on productivity**

Fig 4.36 depicts interaction among height, light and productivity. Productivity was found maximum in squatting posture, followed by standing posture and least in sitting posture while operating the machine. Light has shown no effect on productivity.

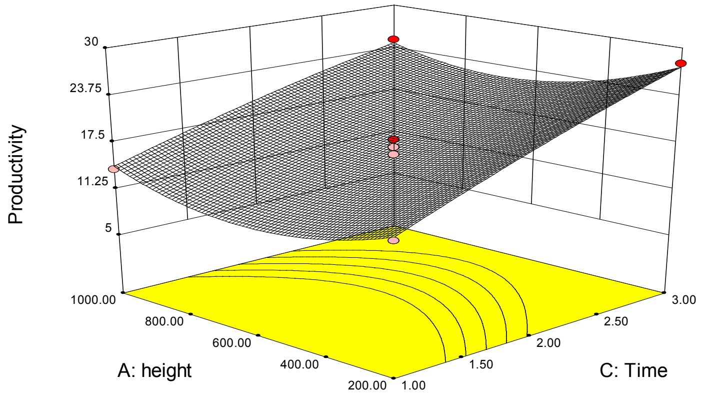



**Fig 4.37: Effect of height and time on prodctivity**

Fig 4.37 depicts interaction among height, time and productivity. Productivity was found maximum in squatting posture, followed by standing posture and least in sitting posture while operating the machine. productivity was incresing continously with time.

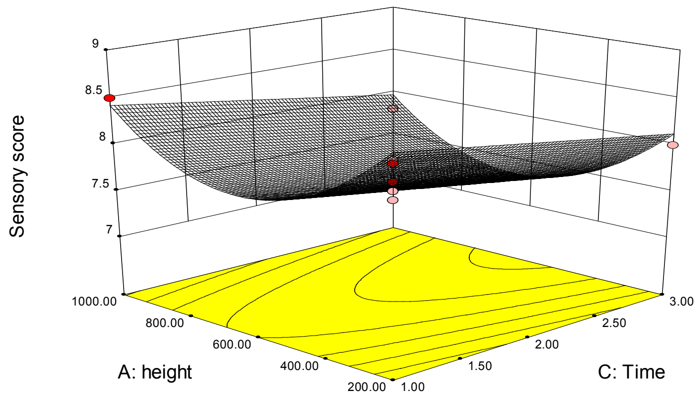



**Fig 4.38: Effect of height and time on sensory score**

Fig 4.38 depicts interaction among height, time and sensory score. Preserve prepared from *aonla* fruits pricked at squatting height and standing height obtained maximum sensory score. However, sensory was decreasing with time.

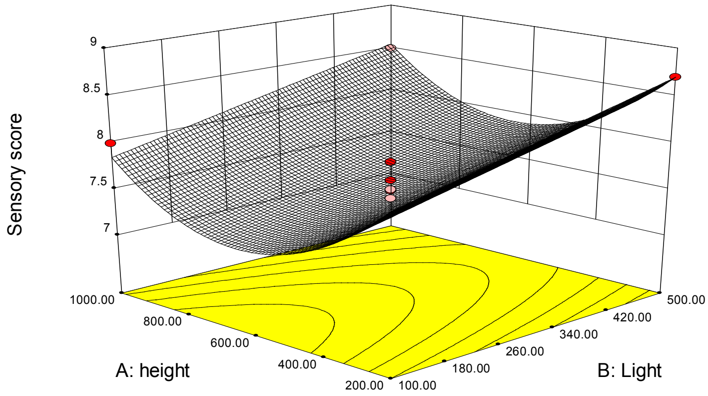



**Fig 4.39: Effect of height and light on sensory score**

Fig 4.39 depicts the interaction among height, light and sensory score. Preserve prepared from *aonla* fruits pricked at squatting height and standing height and pricked around 500 lux light obtained maximum sensory score.

**Optimization of parameters**

The optimum condition for each process variable along with the predicted values of responses and overall desirability are given in table 4.25. The best optimized conditions obtained were working by sitting at 200 mm stool with machine placed at ground level, at light intensity of around 300 lux and working for 1.45 hrs. The next best optimized conditions obtained were working at standing height with machine placed at 1000 mm height, at light intensity of around 300 lux and working for 1.30 hrs. Working in this combination would result into minimum increase in HR and BPDS while pricking task and maximum increase in productivity along with good quality pricking.

**4.25: Optimization of parameters**

| Runs | Coded process variables | | | Responses | | | | Desirability | |
|---|---|---|---|---|---|---|---|---|---|
| | Height (mm) | Light (lux) | Time (hrs) | HR (beats.min$^{-1}$) | BPDS | Productivity (Kg/h) | Sensory Score | | |
| 1 | 200.00 | 314.36 | 1.75 | 91 | 37.37 | 20.11 | 8.43247 | 0.728546 | Selected |
| 2 | 1000.00 | 314.79 | 1.45 | 94 | 45.52 | 16.58 | 8.34892 | 0.530204 | |

Height: range, Light : range, Time : range, HR : minimum, BPDS:minimum, Productivity: maximum, Sensory: range

Thus, from the RSM analysis of all the three tools showing various combination of process parameters and responses, the following best combinations were obtained:

**For conventional tool:** Working at 500 mm height at 500 lux light for 2 hr time.

**For machine:** Working at 200 mm height at 300 lux light for 1.75 hr i.e. 1 hr 45 min. time or working at standing posture with machine placed at 1000 mm height at 300 lux light for 1.45 hr i.e. 1hr 30 min. time.

After pricking work for 2 hr with conventional tools in sitting posture and 1.45 hrs/1.30 hrs work with machine in squatting and standing posture, workers should either alternate their postures or should take rest of 15-20 min.

### 4.3.3 Application of WISE in *aonla* preserve making enterprises

On the basis of the results obtained after the field survey and observational studies of all four *aonla* preserve making enterprises, improvements were suggested to overcome the existing problems in these enterprises that in turn are thought to improve productivity of the workers while keeping them safe (table 4.26). The existing problems were categorized in accordance with Kogi's Checklist depicting problems in material storage and handling, workstation design, work environment and work organization. There were unorganized workplaces and storage in all the units hence, better organized work places and storage were planned like storage of raw material at place of first use, easy to handle containers placed nearby, separate storage shelves for each item and easy reach for work items within the workstation/workplace. Regarding, workstation design, there were no proper workstation in all the units, so a proper sit-stand workstation was designed and its prototype was developed. *Aonla* pricking machine was introduced in these units to replace the conventional tools. The replacement of conventional tools with machine and development of workstation was thought to reduce small hand tool injuries and exposure of workers to WRMSDs. Use of safety measures like gloves and finger tools were also suggested to the workers. There was poor lighting, ventilation, inappropriate temperature in all the units which was planned to overcome by installing artificial light sources near working areas, by shifting workstation near windows and providing exhaust fans respectively. Proper work rest allowances were also determined for the workers by using RSM methodology which states that conventional tools should be operated for 2 hr while sitting on chair and then workers should take 15-20 min rest. The machine should be operated for 1 hr 45 min and 1 hr 30 min in squatting posture and standing posture respectively and then the workers should take rest of 15-20 min. along with providing them productive work environment. Healthy work environment was also planned to be promoted among workers.

**Table 4.26: Improvements suggested for preserve making industries based on WISE methodology**

| Existing problems | Improvements suggested |
|---|---|
| **I. Material storage and handling** | |
| Unorganized work place and storage | **Better organized work place and storage** |
| | -Storage of raw material at place of first use.<br>-Easy to handle containers placed nearby.<br>-Separate storage shelves/racks for each item.<br>-Easy reach for work items. |

| | |
|---|---|
| **II. Workstation design** | |
| No workstation in existing method | **Development of proper workstation** |
| | -Proper sitting area and working platform as per anthropometric dimensions of user population.<br>- Frequently used item within the "reach envelop". |
| Poorly designed hand tool | **Introduction of efficient machinery** |
| | -A hand operated *aonla* pricking machine developed by AICRP on PHT, Hisar. Machine is cost effective, easy to handle with a pricking capacity of 15-20 kg *aonla*/hr. |
| Hazards in existing method | |
| 1.Small hand tool injuries | **Use of safety measures** |
| | -Safety measure like gloves and finger guards. |
| 2.WMSD's | **Improved posture** |
| | -Sit-stand workstation to alternate postures.<br>-Working at elbow height.<br>-Adjustable height of work tables, chairs.<br>-Enough clearance on worktable. |
| III. **Work environment and work organization** | |
| Poor work environment | **Maintain a comfortable work environment** |
| 1. Poor lighting | -Install artificial light sources near working areas.<br>-Workstation shifted near window. |
| 2.Poor ventilation | -Provision of exhaust fan. |
| 3.Inadequate temperature | -Proper ventilation. |
| Tight work schedule | **Provision of work rest allowance** |
| | -Self paced work- short breaks in between work. |
| Poorly productive work environment | **Productive work environment** |
| | - Healthy environment, pleasant surroundings and motivating workers by providing them user friendly machinery to increase their productivity. |

## CHAPTER–V

## DISCUSSION

This chapter presents the discussion regarding the findings of the study. The relevant discussion has been presented under the following sub heads:

5.1 Working conditions of *aonla* preserve making SMEs and work profile of workers

5.2 Ergonomic evaluation of conventional and improved methods of *aonla* pricking, user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared

5.3 Development of workstation, optimization of process parameters using RSM and application of WISE methodology

### 5.1. Working conditions of *aonla* preserve making SMEs and work profile of workers

**Environmental working condition of the workplaces of *aonla* preserves making units**

Results pertaining to the measurement of environmental condition within all the units in terms of lighting, temperature, humidity and noise level clearly states that the lighting levels were very poor, temperature was high, however, humidity and noise levels were within the acceptable limits. Bhavani (1990) reported that visual distraction and fatigue may occur after prolonged work under poor lighting condition. This all has increased the occurrence of hand tool injuries among workers. Similarly, high temperature within the units was also attributed to lack of proper ventilation. Emphasizing on the temperature, Lal (1996) stated that important aspect of comfort is temperature and it is maintained through providing proper ventilation within the units.

The walk through investigation of these units revealed that the existing working conditions and processing tools and techniques were not safe for the workers and can result into development of occupational health hazards. All the four enterprises were running in poorly designed 1-2 rooms having poor ventilation, poor hygiene, poor drainage and unorganized storage facilities. Further, the pricking task was carried out with conventional tools without proper grip and sharp pricking edges. Constrained and sustained work posture for prolonged time especially sitting posture with forward bent position of neck, back, flexed arms and folded legs were adopted by workers while pricking. Workers of all the four units were not using any protective measures like gloves to safeguard their fingers from sharp edges of pricking tools. Thus, workers were suffering from minor finger injuries to severe WRMSDs. A combination of such ergonomic stressors exposes the workers to a high risk of development of WRMSDs. The findings of study are in accordance with the study conducted by Tikoo and Ogale (2001) on occupational health problems of women workers which revealed that that work factors like posture at work, work duration and work movement are the major sources of occupational health problems which needs remedial measures.

**Work profile of workers**

All the workers were laborers and unskilled and used to work for 50-60 hrs/week .Majority of the workers felt that pricking task is labour intensive and physically demanding. They get exhausted after the work and find difficulties in existing methods. The difficulties faced by them were the main reason for their low productivity and development of WRMSDs. However, no changes have been introduced in the existing methods either by the workers themselves or by the owner of the enterprises.

Most of the workers (95%) have suffered from minor finger injuries from the sharp edges of the pricking tools and the injuries were cuts, irritation, swelling, stiffness, numbness, laceration and contusions. The injuries were because of poor design of hand tools and improper lighting in the pricking area. This would have resulted into reduced pricking capacity of the workers.

## 5.2. Ergonomic evaluation of conventional and improved methods of *aonla* pricking, user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared

The experiment was conducted on 15 women respondents. The mean age, weight and height of the workers were found to be 30.25 years, 55.4 kg and 158.66 cm. Physically fit women workers were selected to obtain the most accurate results. Body temperature, blood pressure, body mass index (BMI), body composition and physical fitness index (PFI) of all the workers were within the normal range. The workers had a mesomorph body type indicating a good body built.

### 5.2.1 Ergonomic evaluation of the pricking task

#### 5.2.1.1 Cardio-respiratory responses of the workers while working with conventional and improved methods of *aonla* pricking

While working with the fork, maximum increase in working HR was found in squatting posture followed by standing posture and least in sitting posture. The increase in working HR with the hand tool showed same pattern as that of the fork. With the machine, the increase in working HR was found to be maximum in squatting posture, followed by sitting posture and least in standing posture. With the fork and hand tool the maximum increase in HR was found in squatting posture which can be attributed to the fact that squatting posture is the most taxing posture for the body and therefore, should be avoided as much as possible. The HR was slightly more in standing posture than in sitting posture, matching to several findings which spell out that work should be carried out preferably more in sitting posture than in standing posture. However, with the machine, the HR showed maximum increase in squatting posture than in sitting and least increase was observed in standing posture. This is attributed to the fact that, the workers were not comfortable to operate the machine in sitting posture as machine in sitting posture was not within the easy reach of the workers. Operating machine in sitting posture involved greater flexion of the upper extremities, which indirectly affected their HR.

Hence, it’s clear from the above values that HR of all the workers was more or less same while working with fork and hand tool. While working with machine, the HR was slightly more as compared to conventional methods. According to the classification of the workload on the basis of HR given by Varghese *et al* (1995), the activity with three tools in all the three postures can be considered as light activity.

A similar trend was observed in the values of EER, TCCW and PCW. Grandjean (1980) reported that in squatting posture the energy consumption for a given task is 30-35% more as compared to sitting/standing postures, therefore, work in squatting posture should be avoided.

From the above results, it can be concluded that the heart rate, energy expenditure rate and physiological cost of work while working with all tools in various postures were within the acceptable limits for Indian women workers (Saha *et al.* 1973), hence, didn’t play crucial role in determining preference of using improved tool over conventional tools.

#### 5.2.1.2 Biomechanical responses of the workers while working with conventional and improved methods of *aonla* pricking

**Grip fatigue**

The grip fatigue was found to be maximum with the fork attributed to the shape of fork handle that doesn’t suit to the grip of palm muscles, followed by hand tool and minimum with the machine. The hand tool and machine handles well fits within the grip of human hand and thus were easy to operate. While working with the fork and hand tool, the grip fatigue was found to be maximum in squatting posture, followed by sitting and least in standing posture. This may be attributed to fact that in squatting posture body is not fully balanced which also affect strength and stability of the grip muscles. Further, there was no proper workstation and pricking in sitting and squatting postures was carried out on ground, thus involving greater flexion of upper extremities and thus causing more stress on muscles. While with the machine the grip fatigue was found to be maximum in sitting posture as it was difficult for the workers to operate machine in sitting posture, followed by squatting posture and least increase was observed in standing posture. In squatting as well as in standing postures, the machine was within the easy reach of the workers, hence less stress was experienced by the palm muscles of the workers.

**Postural analysis of workers using RULA and OWAS**

The action categories obtained while pricking with the conventional tools and improved method clearly indicates that the investigations were needed and changes were required in working postures. The postural problems were mainly due to lack of proper workstation. The high flexion of upper extremities while using both conventional tools as well as machine can be eliminated if there is presence of proper workstation at a suitable working height and within the easy reach of the workers. However, there is no alternative for force exertion and highly repetitive motion of wrist joint while working with fork and hand tool, hence, working with these tools should be eliminated as far as possible. Similarly, working by sitting on ground and squatting postures either should be eliminated or modified. This all has given rise to the importance of developing a proper sit -stand workstation for the workers to lower down their risk in developing MSDs. Kumar (2001) reported that any force exertion, repetition of activities or assuming one particular posture for prolonged period imposes stress on human system and should be changed.

**Spinal angle deviation while working with different tools in various postures**

The spinal deviation was found to be maximum with the fork and hand tool in squatting posture followed by sitting posture and least in standing posture. However, with machine the spinal deviation was found to be maximum in sitting posture, followed by squatting and least in standing posture. Excessive spinal deviation is considered very harmful for the workers as it exposes them to a risk of development of low back pain (LBP). This indicates towards elimination of squatting posture while working with the fork and hand tools and elimination of sitting posture while working with the machine.

From the above results, it can be concluded that grip fatigue, RULA and OWAS analysis and spinal angle deviation all indicates towards complete replacement of conventional tools with machine and development of proper workstation for working on machine along with modifications in working postures.

### 5.2.1.3 Psycho-physical responses of the workers while working with conventional and improved methods of *aonla* pricking

**Rating of perceived exertion (RPE) experienced by the workers**

The RPE score while working with all the 3 tools in different postures varied between 2-3, thus categorizing the work as ranging between light to moderately heavy. With the fork and hand tool, the pricking work in sitting and standing posture was rated by workers as light and in squatting posture it was heavy. However, with machine the pricking task in sitting posture was rated by workers as moderately heavy while in squatting and standing postures it was considered as light activity. The reason attributed to this is same as attributed to the increase in WHR.

**Visual Analogue Discomfort (VAD) experienced by the workers**

VAD score was found to be same as that of RPE score and seeks the same explanation as that of RPE. With fork and hand tool, more workers were facing moderate to high discomfort in squatting posture and with machine, more workers were facing moderate to heavy discomfort in sitting posture.

**Body part discomfort (BPDS) experienced by the workers**

BPDS was found to be maximum with the fork as well as hand tool in squatting posture and with the machine in sitting posture. The reason attributed to this is same as that attributed to RPE and VAD scores.

Vibha and Sangwan (2007) also found out that incorrect posture sustained for a long period of time while performing chapatti rolling activity give rise to discomfort and various musculoskeletal problems in different body parts.

**Nordic musculoskeletal analysis of pricking task**

As it is clear from the RULA results that working with hand tools involved highly repetitive motion of right hand especially high back and forth movement of wrist joint, therefore workers were suffering from more discomfort in right hand than in left hand. Whereas, the use of machine didn't involve high repetitive motion of upper extremities, hence problem/discomfort experienced by workers was very low. Working in awkward postures for prolonged duration have further added to their problems like pain in lower back, neck, shoulders etc. Similar results were obtained by Barman *et al*. (2009) while studying WRMSD's of female fish processing workers in West Bengal who suffered from wrist (60%), neck (56%), lower back (54%) and shoulder (50%) pain as they were involved in a highly repetitive work of peeling in awkward postures.

From the above results, it can be concluded that RPE, VAD score, BPDS score and NMQ analysis all indicates towards modification in the working postures.

### 5.2.2 Acceptability and economic benefits of *aonla* pricking machine

**User's acceptability of *aonla* pricking machine**

The machine was well accepted by majority of the workers as they felt that machine was time, labour and drudgery saving, simple to operate and maintain and also they were very much satisfied with the working of the machine. Further, there were no finger injuries and eye aches while working on the machine.

**Economic benefits associated with use of *aonla* pricking machine**

With the machine, workers were able to prick twice the amount of *aonla* as compared to the conventional tools, thus, resulting into saving of time, human energy and cost of pricking along with good quality of pricking as has been determined by the organoleptic evaluation of preserve prepared with the machine pricked *aonla*.

### 5.2.3 Analysis of organoleptic quality, vitamin C content and water activity of the preserves

**Total sensory score of preserve prepared under different treatments**

The reason attributed to the difference in the sensory scores of preserve prepared under different treatments was the difference in the quality of pricking. Machine pricking resulted into uniform pricking *i.e.* size and depth of pricks were uniform and appropriate, thus resulting into uniform penetration of sugar syrup throughout the whole fruit. The use of fork and hand tool resulted into non uniform pricking. However, with hand tool the pricks made were somewhat large, thus facilitating better flow of sugar within the fruits as compared to small pricks made by the small needles of fork.

**Ascorbic acid retention of preserve prepared under different treatments**

The reason attributed to the difference in ascorbic acid retention of preserves prepared under different treatments was the loss of ascorbic acid during the pricking task. Since machine resulted into uniform pricking, thus the loss of fluid from the fruits while pricking was less, however with hand tool the pricks made were large hence loss of fluid was more from the fruit. Further many times, pricking with fork and hand tool resulted into damage to the fruit as 2-3 pricks were made at same place, hence resulting into more fluid loss from the fruit causing direct loss of vitamin C (ascorbic acid).

**Water activity of preserve prepared under different treatments**

Water activity of the preserve is a measure of availability of the free water within the prepared preserve. Low water activity is an indication that sugar has penetrated very well within the fruit and has bound the free water. Low free water means low microbial growth as micro-organism need free water for their survival and thus, absence of microbial activity is an indication of good shelf life. *Aonla* fruits having uniform size and depth of pricks with good penetration of sugar were having least water activity.

The results obtained are in accordance with that of Kumar (2003) who found that *aonla murabba* prepared by machine pricking retained higher ascorbic acid than hand pricked ones. The product obtained slightly higher score in sensory evaluation compared to hand pricking method.

Hence, from the results of this phase, it can be concluded that the machine was found to be advantageous over the conventional tools both ergonomically and economically. Though the cardio-respiratory responses were slightly higher while working with the machine as compared to the conventional tools, but the responses with the machine were also within the acceptable limits for women workers. It clearly indicates that HR doesn’t offer the solution to make choice between the conventional tools and pricking machine. Regarding, biomechanical parameters, grip fatigue, spinal deviation and repetitive motion of the upper extremities were higher with the conventional tools as compared to the machine. However, working with machine also resulted into biomechanical stress but of very low severity. This was mainly attributed to the lack of proper workstation. The biomechanical stress is not considered good for workers as in long run it may expose them to development of severe MSDs especially that of the upper extremities. Similarly, psycho-physical parameters were also high with conventional tools as compared to the machine. It is, therefore, suggested that either conventional tools should be replaced with the machine or a proper workstation should be developed for both the conventional tools and machine to lower associated biomechanical stress.

Therefore, it was planned under the study to develop a workstation based on the anthropometric dimensions of women workers and then to modify sitting on ground (S1), squatting (S2) postures with sitting on chair and low stool sitting postures keeping standing posture (S3) as such. The workstation was designed as such its height can easily be adjusted according to the comfort level of the workers.

## 5.3 Development of workstation, optimization of process parameters using RSM and application of WISE methodology

### 5.3.1 Development of prototype workstation

A sit-stand workstation prototype was developed keeping into consideration various anthropometric dimensions of the workers. The body dimensions taken were standing anthropometric dimensions for determining height range of the workstation, sitting anthropometric dimensions to design the chair in accordance with the dimensions of the workstation, hand and arm dimensions to determine the distance between chair and workstation and afterwards to determine the length of handle of the machine and normal and maximum reaches to determine the depth and width of the workstation and the layout of various required items on the workstation.

### 5.3.2 Optimization of the process parameters using Response surface methodology

**From RSM analysis of fork pricking, following interesting points emerged**

**Effect of Height-Light-Time on HR in fork pricking in fork pricking**

1. While working with fork, working HR was found least in sitting at 600 mm chair height and then HR has started increasing on moving to the either sides *i.e.* towards low stool height and standing height with maximum increase at standing height. This indicates that workers were very comfortable at sitting height with workstation accordingly adjusted.
2. Light showed no effect on HR.
3. With increase in time, HR has shown a continuous and sharp increase. With time workers were developing fatigue, hence HR was increasing.

The HR of all the workers while working in all the 17 combinations of the independent variables was less than 105 beats.min$^{-1}$, hence, was within the acceptable limit for the women workers (Saha *et al.* 1973).

**Effect of Height-Light-Time on BPDS in fork pricking**

1. BPDS was found to be minimum at sitting height and then HR has started increasing on moving to the either sides of *i.e.* towards low stool height and standing height with maximum increase at standing height. The body of the workers especially the upper and lower extremities, neck and backbone were well balanced in sitting posture on chair, hence low discomfort was experienced.
2. Light has very negligible effect on BPDS. While working at low intensity light, workers has to hold the fork very tightly otherwise they may hit their fingers with it. This was causing more fatigue and discomfort in palm muscles as compared to the pricking work which was carried out in proper lighting.
3. With increase in time, BPDS has shown a continuous and sharp increase. As time was increasing, workers working in a fixed posture were experiencing discomfort.

The BPDS experienced by the workers in all the 17 combinations of the independent variables was found to be moderately heavy.

**Effect of Height-Light-Time on productivity in fork pricking**

**1.** Productivity was found to be maximum at sitting posture and then it has started increasing on moving to the either sides of *i.e.* towards low stool height and standing height with maximum increase at standing height. Workers were very comfortable in sitting posture, hence were able to prick the fruits more easily.

**2.** Productivity was maximum at around 300-400 lux light and low at 100-200 lux light. At low intensity light, workers have to be very careful about the pricks to be made and this attention seeking task delays their work, while at proper lighting the pricks made were very clearly seen and workers didn't have to waste time in properly checking them.

3. With increase in time, productivity has shown a continuous and sharp increase. As time was increasing the amount of *aonla* pricked was also increasing.

**Effect of Height-Light-Time on sensory in fork pricking**

**1.** Sensory was maximum at sitting posture then it started decreasing on moving to the either sides *i.e.* towards low stool height and standing height with maximum decrease at standing height. At sitting posture, workers were very comfortable, so the quality of pricking in terms of depth and number of pricks were uniform, thus, the quality of preserve prepared was also good.

**2.** Sensory increased with light. In presence of proper lighting workers were able to make uniform pricks throughout the surface of *aonla* fruit, thus facilitating better absorption of sugar.

**3.** Sensory was decreasing with time. With increase in time, the workers were developing fatigue in palm muscles, thus affecting the depth of pricking done by them in turn affecting the uniform absorption by the pricked fruits.

The most desired combination of height-light-time that would result into minimum increase in HR and BPDS and maximum increase in productivity keeping sensory in range while working with fork was found at: **Working at 500 mm height at 500 lux light for 2 hr.**

From this it may be concluded that for longer hour work with hand tools sitting posture should be used. The workers were comfortable at sitting height for long duration work. When they were comfortable, so the increase in HR was normal and BPDS were also low and productivity was maximum along with good quality of pricking. Hence, the results are in accordance with all the studies mentioned in the review of literature that states that for longer duration activities more sitting should be promoted and alternate sit- stand workstation should be designed to decrease the risk of MSDs among workers and increase their productivity.

After 2 hour pricking in sitting postures workers should be promoted to carry out pricking in standing posture for 15 minutes by adjusting the height of workstation, then again should proceed with sitting posture or they should take the break of 15 minutes.

With hand tool, the RSM results were more or less the same as with fork, hence, are not discussed here.

**From RSM analysis of machine pricking, following interesting points emerged**

**Effect of Height-Light-Time on HR in machine pricking**

1. While working with machine, working HR was found to be slowly increasing with height with minimum HR at low stool height and then at standing height. This indicates that while operating the machine, workers were very comfortable either at low stool height with machine placed near ground level or by operating machine at standing posture with workstation accordingly adjusted.
2. Light has no effect on HR.
3. With increase in time, HR has shown a continuous and sharp increase. As with time workers were developing fatigue, hence HR was increasing.

The HR of all the workers while working in all the 17 combinations of the independent variables was less than 105 beats. $min^{-1}$, hence, was within the acceptable limit.

**Effect of Height-Light-Time on BPDS in machine pricking**

1. BPDS was found to be increasing with increase in height with minimum BPDS recorded at low stool height as to operate the machine near the ground level the workers were facing very less discomfort in upper extremities.
2. Light showed no effect on BPDS while operating the machine.
3. With increase in time, BPDS has shown a continuous and sharp increase. As time was increasing, workers working in a fixed posture were experiencing discomfort.

The BPDS experienced by the workers in all the 17 combinations of the independent variables was found to be moderately heavy.

**Effect of Height-Light-Time on productivity in machine pricking**

1. Productivity was found to be maximum at low stool height and then was decreasing with increase in height and then again has started increasing with increase in height.
2. Light was found to have no effect on productivity.
3. With increase in time, productivity has shown a continuous and sharp increase.

**Effect of Height-Light-Time on sensory in machine pricking**

1. Sensory was maximum at low stool height which started decreasing with increase in height and then again started increasing with increase in height. Since, workers were comfortable either in low stool posture or standing posture, hence they were able to prick more amounts of fruit.
2. Sensory was found increasing with light. As with proper lighting workers were better able to check the uniformity of the pricks throughout the surface of the fruit. In case of improper pricking they used to prick the fruit again.
3. Sensory was found decreasing with time. With time workers were developing fatigue, hence not able to operate the machine properly thus, affecting the depth of pricks.

The most desired combination of height-light-time that would result into minimum increase in HR and BPDS and maximum increase in productivity keeping sensory in range while working with fork was found at: **Working at 200 mm height at 300 lux light for 1 hr and 45 min** or **Working at standing posture with workstation accordingly adjusted near 1000 mm height (elbow height) at 300 lux light for 1hr and 30 min**.

From this it may be concluded that for longer duration work with machine, low stool posture or standing posture should be used. The workers were comfortable at low stool height or at standing posture while operating the machine for longer duration work. When they were comfortable, so the increase in HR was normal and BPDS were also moderate and productivity was maximum along with good quality of pricking. The reason attributed to this is that the low stool posture was taking the advantage of gravity, hence, work was carried out at minimum expenditure of the energy. Vos (2007) also pointed out that if work has to be carried out in the ground itself, then sitting on low stool appears to be the most favorable position. At standing height, machine was within the easy reach of workers, hence, they were able to operate it easily therefore, should be promoted.

After 2 hour pricking in low stool postures workers should be promoted to carry out pricking in standing posture for 15 minutes by adjusting the height of workstation, then again should proceed with sitting posture or they should take the break of 15 minutes. The standing posture after 1.30 hrs work should either be changed or the workers should take the rest of 15 minutes.

### 5.3.3 Application of WISE in *aonla* preserve making enterprises

As per WISE, improvements were suggested for preserve making enterprises based on the results of walk through investigations of the units. The existing problems in the SMEs were regarding material storage and handling, workstation design, work environment and work organization. The problems observed were unorganized workplaces and storage, absence of proper workstation, use of poorly designed hand tools, consequently, workers were suffering from WRMSDs and small hand tool injuries. Poor lighting, poor ventilation, inappropriate temperature, tight work schedule were other prominent problems observed in the SMEs. The improvements suggested were development of proper workstation with adequate provision of storage, introduction of efficient machinery such as hand operated *aonla* pricking machine, use of safety gloves, maintenance of comfortable work environment including provision of artificial lighting, exhaust fan or shifting workstation near windows and most important provision of work rest allowances as determined by RSM results. The implementations suggested were in accordance with ergonomic checkpoints given by Kogi (1985).

**CHAPTER-VI**

## SUMMARY AND CONCLUSIONS

The *aonla* preserve *(murabba*) is one of the specialties of the Indian fruit preservation industry selling hundreds of tons of preserve every year. Women are vital and most productive workers in preserve making small-medium enterprises (SMEs). Till date, in preserve making enterprises pricking is done using conventional hand tools with sharp pricking edges and improper grip due to non availability of suitable pricking tool. These manual methods are laborious and time consuming and cannot maintain the quality of the final product (preserve). Minor accidents like cuts and wounds in the fingers and disorders of upper extremities also have been reported during manual pricking due to high vision demanding and repetitive nature of the pricing task. This all has resulted into lowered productivity of the workers.

Keeping this in view, a hand operated *aonla* pricking machine has been developed by All India Coordinated Research Project on Post Harvest Technology (AICRP on PHT), in College of Agricultural Engineering and Technology, CCSHAU. The machine consisted of oppositely situated teflon hemisphere blocks with 50 stainless needles mounted on each block for pricking *aonla* fruits.

To be on the safer part every machine whether large or small must undergo an ergonomic assessment to avoid man –machine conflict in the work place which in turn will enhance worker efficiency and productivity. The ergonomic study will cover the work place layout, working conditions and man-machine aspects with the ultimate aim of enhancing the efficiency with which work is done and at the same time keeping in consideration the safety and comfort of the worker involved. Based on the above rationale, the present study was undertaken with the following specific objectives:

1. To examine the existing working conditions, processing tools and techniques of *aonla* pricking units
2. To conduct ergonomic evaluation of conventional and improved methods of *aonla* pricking
3. To study user's acceptability of *aonla* pricking machine and organoleptic quality of the preserve prepared

The present study was conducted in three phases. The first phase comprised of field survey of four *aonla* preserve making SMEs selected from Hisar, Kaithal and Jind districts of Hisar, Haryana. A sample of 30 women workers was selected randomly from selected SMEs and thereafter environmental working condition and personal and working profile of workers were studied using observational studies and interview schedule. Phase second comprised of ergonomic evaluation of conventional (fork and hand tools) and improved methods (hand operated *aonla* pricking machine) of *aonla* pricking, user's acceptability of *aonla* pricking machine and organoleptic quality of preserve prepared. This phase consisted of experiment work conducted with 15 women workers. The ergonomic cost of pricking activity with all the three tools in three different postures *i.e.* sitting on ground (S1), squatting (S2) and standing (S3) was carried out. The physiological responses of the workers while pricking activity were measured in terms of HR, EER and PCW, biomechanical stress were measured in terms of grip fatigue, postural analysis and spinal deviation and psycho-physical parameters were measured using RPE, VAD, BPDS and NMQ. A well structured questionnaire was used for finding user acceptability of the machine. Economic benefits associated with the use of machine were calculated in terms of output, quality pricked, energy, time and cost saved. For checking organoleptic quality of the product, three types of preserve were prepared with variation in pricking tools *i.e.* with fork, hand tool and *aonla* pricking machine followed by total sensory, vitamin C and water activity estimations of prepared preserve. Phase third comprised of development of workstation based on anthropometric dimensions of user population of first phase, optimization of process parameters using RSM to find out the best combination of height-light-time on workstation and then, suggestions were planned for selected SMEs using WISE methodology.

**Major findings of the study are**

- All the SMEs were characterized by inappropriate workplaces, poor working environment in terms of lighting and temperature, poor ventilation, hygiene and drainage. Work profile of workers revealed that pricking of *aonla* was carried out mostly by sitting posture. Pricking task was highly repetitive done manually, characterized by fast and repetitive movements of the upper extremities exposing workers to MSDs. Pricking tool was old and poorly designed having improper grip diameter and sharp pricking edges resulting into grip fatigue along with health hazards viz. cuts, irritations, lacerations etc on fingers of workers. No protective measures were used by the workers to save fingers from smaller injuries. The pricking task was tiresome, time consuming and burdensome to workers. Inadequate as well as irregular rest pauses for the workers and there was no provision of proper work rest allowance.
- Physiological parameters like HR, EER and PCW were found to be slightly higher while pricking with the machine as compared to the conventional tools. The squatting posture was found to be most tedious posture while pricking with all the three tools followed by sitting and standing postures.

  HR has shown maximum increase while working with machine in squatting posture (90 beats.min$^{-1}$)

  However, the physiological responses with all the three tools in all the three posture were within the acceptable limit for the women workers and pricking with all the tools in all the postures was regarded as the light activity based on the values of HR and EER. Hence, physiological parameters didn't play a crucial role in determining preference of using improved tool over conventional tools.

- Regarding biomechanical parameters, the grip fatigue of right and left hand was found to be highest with fork (26 %), thus indicating towards the elimination of use of fork for longer duration of *aonla* pricking. With hand tool as well as machine the problem of grip fatigue of right hand was not very much prominent as the handle of both the tools fits well within the grip of human hand. However, unlike machine, working with fork and hand tool also resulted into grip fatigue of left hand thus making the task tedious after few minutes of pricking. With machine workers experienced very less fatigue in left hand. Hence, the working with fork and hand tool was found to be comfortable for few minute pricking but not for long hours work.

  The postural analysis of workers in different working postures using RULA indicates towards complete elimination of use of conventional tools as they involved exertion of force and highly repetitive motion of upper extremities. Machine pricking also involved high flexion of upper and lower arm because of absence of proper workstation. Similarly, OWAS results also clearly indicate that working in sitting and squatting posture with all the three tools should be changed as soon as possible. Spinal deviation was also found to be maximum in squatting posture with conventional tools and in sitting posture with machine. Hence, the biomechanical parameters clearly states towards complete elimination of use of conventional tools and promotion of the machine and at the same time modifications in sitting and squatting postures with the development of a proper workstation.
- Regarding psycho-physical responses, RPE, VAD and BPDS and MSDs were found to be maximum with fork and hand tools in squatting posture, followed by standing posture and least in sitting posture. Whereas, with machine the discomfort was highest in squatting posture, followed by sitting and least in standing posture. This was mainly because of working in wrong posture along with lack of proper workstation. This, hence, promotes development of proper workstation and modifications in working postures.
- There was high acceptability of the machine reported by the users in terms of relative advantage with use of machine, compatibility with use of machine, simplicity of machine and satisfaction with the use of machine. However, 23.2 percent workers reported that they didn’t find machine suitable.
- With the use of machine workers were able to prick twice the amount of *aonla* as compared to the conventional tools. With machine in 20 min workers were able to prick 45-60 number of *aonla* in various postures whereas, with conventional tool the amount pricked in 20 min was only 25-32 number of *aonla* in various postures. Consequently, there was saving in time, human energy and cost of pricking while working with machine.
- The total sensory score, ascorbic acid retention were found to be maximum with machine pricked *aonla* preserve indicating towards its high acceptability among users whereas, the water activity of machine pricked *aonla* preserve was found to be minimum indicating towards its good shelf life.

It was interpreted after this experiment that posture alone doesn't affect the ergonomic cost of work, but the environmental condition especially lighting in the units and the time spent on the activity were the other factors that have maximum impact on the ergonomic cost of work. Keeping this in mind, the study was continued with 3 independent variables viz. posture, light and times to determine their effect on ergonomic and economic parameters. Hence, a proper sit -stand workstation based on the anthropometric dimensions of the women workers was designed. The Response surface methodology was used to find the best combination of independent variables that yielded most favorable results while working with all the three tools. The sitting posture was modified with sitting on a chair at 600 mm height with machine placed on accordingly adjusted workstation, squatting posture was modified with low stool posture *i.e.* sitting on 150-200 mm high stool with machine placed on ground and standing posture with machine placed three inches below elbow height according to the convenience of user. The workstation was so designed that workers can alternate their posture according to their comfort level. As it was observed during the field survey that lighting was very poor in all the units and pricks were to be made very carefully in each *aonla* fruit thus it was realized that intensity of light may affect the economic parameters. Hence, three different levels of light intensity were fixed for the experiment *i.e.* 100 lux, 300 lux and 500 lux. Regarding the third variable, time, the workers have to work continuously for 2-3 hrs hence, the time for conducting the experiment was set as 1hr, 2 hr and 3 hr.

- A set of 17 experiments were carried out with each tool *i.e.* fork, hand tool and machine. It is interpreted that pricking with fork and hand tool would yield most favorable results when pricking will be carried out in a combination of: 500 mm height+500 lux light+2 hr time. The workers should be provided with rest after 2 hr pricking with conventional tool or after 2 hr they should alternate their posture and should work in standing posture for 10-15 minutes, then again should continue work in sitting posture. While with machine the best combination of independent variables was found at: 200 mm height+300 lux light+ 1.45 hr time or at standing posture with workstation height at 1000 mm height+300 lux light +1.30 hr time. The workers should alternate their posture after working in such combinations or should take 15 min rest. However, squatting posture with conventional tools and sitting posture with machine were eliminated as the workers were not comfortable to operate tools in such combinations.
- Hence, these improvements derived from the experiment were suggested to selected enterprises as a part of WISE methodology to improve the productivity of the workers while keeping them safe and comfortable.

**Recommendations from the study**

1. Machine should be used in place of conventional tools.
2. Work should be carried out at a proper workstation with conventional tools and machine in the following combination of height-light-time.

**Conventional tool:** Working at 500 mm height at 500 lux light for 2 hr time.

**Machine:** Working at 200 mm height at 300 lux light for 1 hr and 45 min time or working at standing posture with machine placed at 1000 mm height at 300 lux light for 1 hr and 30 min time.

After pricking work for 2 hr with conventional tools in sitting posture and 1hr 45 min/1 hr 30 min pricking with machine in squatting and standing posture, workers should either alternate their posture or should take rest of 15-20 min.

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## ANNEXURE-I

**Design specifications of the machine:**

**Design and development of hand operated *aonla* pricking machine-**

The developed hand operated *aonla* pricking machine consisted of mild steel and gun metal body with compressive spring, plastic handle, teflon square block with semi-spheres on inner side and stainless needles mounted on each sphere.

**Design considerations of machine-**

1. Machine should be portable, simple and easy in operation and maintenance.
2. The design of the machine should be relevant to the physical properties of *aonla* fruit. The surface area of the punching semi-spheres should match the surface area of *aonla* fruit. The machine was designed for pricking of *chakaiya* variety with surface area of 4821 $mm^2$ (Ambrish Ganachari, 2010).
3. The solid density and bulk density of the *chakaiya* variety was used for determining the thickness of the needles. The solid and bulk density of the *chakiya* fruit is 1.063 g/cc and 584.3 kg/m3. (Ambrish Ganachari, 2010).
4. The handle is made up of plastic to avoid the grip fatigue while working and to avoid slippery effect on palm.
5. The needles are made up of stainless steel to avoid rusting which may affect the pricking capacity of needles and may impact the quality of the final product.

**Design specifications of *aonla* pricking machine:**

1 Mild steel and gun metal body with compressive spring.

2 Plastic handle (length=100 mm, diameter=30 mm).

3 Teflon plate (80x80 mm, thickness = 6 mm).

4 Teflon square block (80x80 mm, thickness = 30 mm).

5 Needles (50 on each plate, needle size=50 mm, diameter = 2 mm, material of needle = stainless steel).

6 Guiding needles (for controlling up and down motion of teflon plates and not right and left movement).

7 Punching half hollow (radius=50 mm).

8 Weight of machine=8135 grams

9 Force required to operate the machine = 1.4 kg

10 Output with machine = 15-20 kg *aonla* per hour

**The operation of machine:**

The operation of machine is simple in nature. The *aonla* fruit is placed between the oppositely situated teflon square blocks with 50 stainless needles mounted on each plate. The handle is moved downwards bringing oppositely situated teflon plates and needles together, resulting into pressing action on *aonla* fruit placed between them.

## ANNAEXURE-II

**Assessment of existing working condition of *aonla* pricking units and workers**

**Physical condition of unit-**

1. Location of unit-
2. Light- artificial (__________watt) / natural ( ___________lux)/Both
3. Temperature - __________$^{0}$C
4. Noise - ____________dB
5. Relative Humidity - ________________ %

| **Condition of unit** | **Good** | **Poor** |
|---|---|---|
| 1. Ventilation | | |
| 2. Hygiene | | |
| 3. Drainage | | |
| 4. Storage | | |

**Workers-**

**A. General information:**

1. Name: ______________
2. Age: _______________ (yrs)
3. Sex: Female / Male
4. Height
5. Weight

**B. Working profile:**

1. Status of person – Self/laborer/any other
2. Mention the total number of years that you have been in *aonla* pricking? _________years
3. How long your work day does usually lasts? ________hours
4. When do you begin work? _____________
5. End work________________
6. No of days you work per week? _________ days
7. Do you always have at least one break during your work day? Yes/ No

   If yes,

6. How many breaks do you usually have? _______
7. How long is your usual break? ___________
8. Have you undergone any training to perform pricking activity? Yes/No

   If yes, mention_______________

**C. Description of work tasks**

1. Mention the tools/equipment/apparatus that you use during work.________________

2. Output per day- _______________ (Kg)

3. Posture used while pricking – sitting / standing / bending / squatting / if any other combination, mention it (_______________)

4. What do you feel about work load: light/heavy/very heavy/not so heavy

5. What do you think about working condition: good/very good/not so good

6. Do you feel any difficulty doing *aonla* pricking by existing method: Yes/No

   If yes, mention

7. Have you made any change in the existing method – Yes/No

   If yes, what-

**D. Work accidents and Injuries**

1. Have you ever had an accident or been injured at work? Yes/No

   If yes, mention___________

2. Type of injury- Major/Minor

   Mention-

3. Recovery period- within days/weeks/months/no ----

   Mention-

4. Do you use any protective measures while pricking *aonla*. Yes/ No

   If yes, mention_______________

## ANNAXURE-III

**Ergonomic assessment worksheet of *aonla* pricking workers**

Name of respondent: ___________ Enterprise: ________________

**1. Physical Parameter:**

1. Weight
2. Height
3. BMI
4. Body composition
5. Blood pressure
6. Body temperature
7. PFI

**2. Environmental Parameters:**

1. Temperature
2. Relative Humidity
3. Light
4. Noise

**3. Measurements of physiological responses**

**Heart rate:**

| Time (min) | Resting heart rate | | | Working heart rate | | | Recovery heart rate | | |
|---|---|---|---|---|---|---|---|---|---|
| **1** | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| **2** | | | | | | | | | |
| **3** | | | | | | | | | |
| **4** | | | | | | | | | |
| **5** | | | | | | | | | |
| **6** | | | | | | | | | |
| **7** | | | | | | | | | |
| **8** | | | | | | | | | |
| **9** | | | | | | | | | |
| **10** | | | | | | | | | |
| **11** | | | | | | | | | |
| **12** | | | | | | | | | |
| **13** | | | | | | | | | |
| **14** | | | | | | | | | |
| **15** | | | | | | | | | |
| **16** | | | | | | | | | |
| **17** | | | | | | | | | |
| **18** | | | | | | | | | |
| **19** | | | | | | | | | |
| **20** | | | | | | | | | |

**Other parameters from HR:**

| Treatment | EER | TCCW | PCW | OCR | Force required to operate the tool |
|---|---|---|---|---|---|
| S1 | | | | | |
| S2 | | | | | |
| S3 | | | | | |

S1*= Sitting on ground, S2**= Squatting, S3***= Standing

4. **Measurements of biomechanical responses**

**I: Grip fatigue:**

| Treatments | Before activity | | After activity | |
|---|---|---|---|---|
| | Right | Left | Right | Left |
| S1 | | | | |
| | | | | |
| | | | | |
| **Total** | | | | |
| S2 | | | | |
| | | | | |
| | | | | |
| | | | | |
| **Total** | | | | |
| S3 | | | | |
| | | | | |
| | | | | |
| **Total** | | | | |

**Postural analysis:**

**III: RULA scores while pricking task**

| Posture | Score A (Wrist and arm score + force + Muscle used) | Score B (Neck, trunk and leg score + Force + Muscle used) | Final score | Action category |
|---|---|---|---|---|
| S1 | | | | |
| S2 | | | | |
| S3 | | | | |

**IV: OWAS scores while pricking task**

| Posture | Back | Upper limb | Lower limb | Load | Final score | Action category |
|---|---|---|---|---|---|---|
| S1 | | | | | | |
| S2 | | | | | | |
| S3 | | | | | | |

**Measurements of psycho-physical responses**

**I. RPE scores while pricking task**

| Posture | Discomfort score |
|---|---|
| S1 | |
| S2 | |
| S3 | |

**II: VAD scores while pricking task**

| Posture | Discomfort score |
|---|---|
| S1 | |
| S2 | |
| S3 | |

**III: Body part discomfort score while pricking task**

| Posture | Body parts involved | Degree of discomfort | BPDS |
|---|---|---|---|
| S1 | | | |
| S2 | | | |
| S3 | | | |

**IV: Nordic musculoskeletal questionnaire outcomes**

| Posture | Body parts involved | Duration over which pain experienced |
|---|---|---|
| S1 | | |
| S2 | | |
| S3 | | |

**ANNEXURE –IV**

**RULA observations sheet**

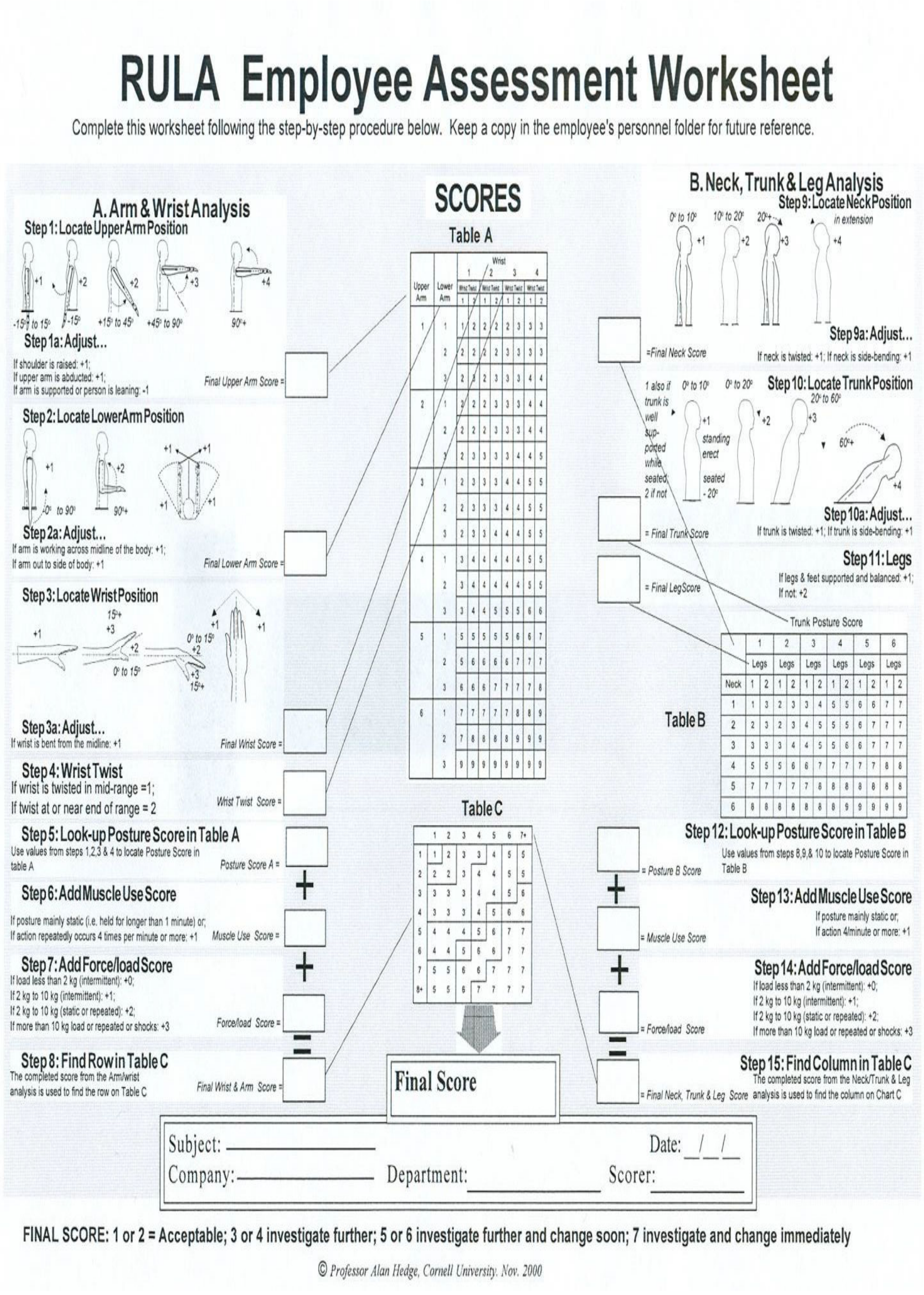



Table A

| Upper Arm | Lower Arm | Wrist 1 Twist 1 | Wrist 1 Twist 2 | Wrist 2 Twist 1 | Wrist 2 Twist 2 | Wrist 3 Twist 1 | Wrist 3 Twist 2 | Wrist 4 Twist 1 | Wrist 4 Twist 2 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 |
| | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 4 | 4 |
| 2 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| | 3 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 5 |
| 3 | 1 | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 5 |
| | 2 | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 5 |
| | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 5 |
| 4 | 1 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| | 3 | 3 | 4 | 4 | 5 | 5 | 5 | 6 | 6 |
| 5 | 1 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 7 |
| | 2 | 5 | 6 | 6 | 6 | 6 | 7 | 7 | 7 |
| | 3 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 8 |
| 6 | 1 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 9 |
| | 2 | 7 | 8 | 8 | 8 | 8 | 9 | 9 | 9 |
| | 3 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

Table B

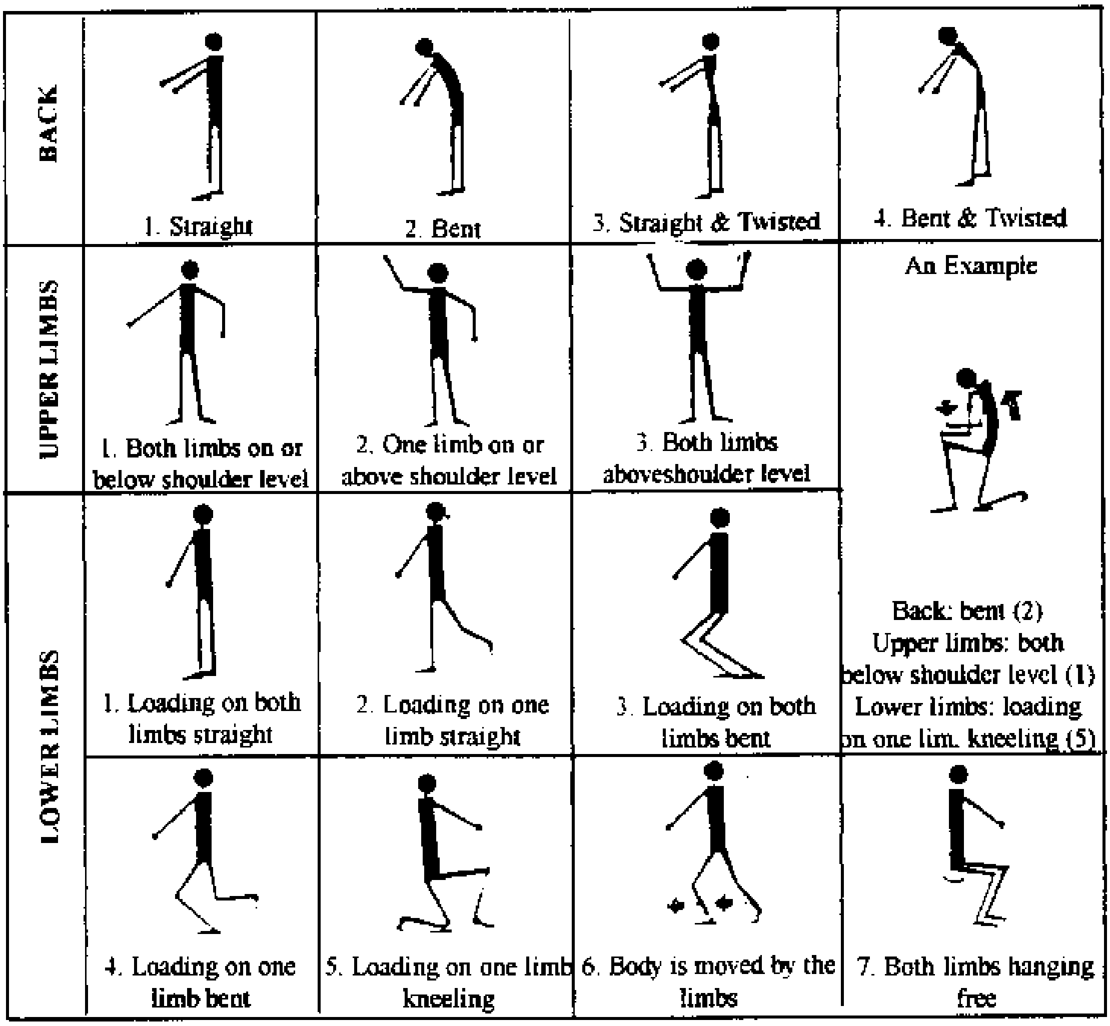
| Neck | Trunk 1 Legs 1 | Trunk 1 Legs 2 | Trunk 2 Legs 1 | Trunk 2 Legs 2 | Trunk 3 Legs 1 | Trunk 3 Legs 2 | Trunk 4 Legs 1 | Trunk 4 Legs 2 | Trunk 5 Legs 1 | Trunk 5 Legs 2 | Trunk 6 Legs 1 | Trunk 6 Legs 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 | 7 | 7 |
| 2 | 2 | 3 | 2 | 3 | 4 | 5 | 5 | 5 | 6 | 7 | 7 | 7 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 4 | 5 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 8 |
| 5 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 6 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |

Table C

| | 1 | 2 | 3 | 4 | 5 | 6 | 7+ |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| 2 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 3 | 3 | 3 | 3 | 4 | 4 | 5 | 6 |
| 4 | 3 | 3 | 3 | 4 | 5 | 6 | 6 |
| 5 | 4 | 4 | 4 | 5 | 6 | 7 | 7 |
| 6 | 4 | 4 | 5 | 6 | 6 | 7 | 7 |
| 7 | 5 | 5 | 6 | 6 | 7 | 7 | 7 |
| 8+ | 5 | 5 | 6 | 7 | 7 | 7 | 7 |

**ANNEXURE – V**

**OWAS observations sheet**



# Annexure-VI

## Nordic musculoskeletal questionnaire

| 'e you at any time during the **last 12** nths had **trouble (such as ache,** n, **discomfort, numbness)** in: | Have you had **trouble** during the **last 7 days**: | During the **last 12 months** have y been **prevented** from carrying ou normal activities (eg. job, housew hobbies) because of this trouble: |
|---|---|---|
| ***Neck*** No 1 ☐ Yes 2 ☐ | **2** ***Neck*** No 1 ☐ Yes 2 ☐ | **3** ***Neck*** No 1 ☐ Yes 2 ☐ |
| ***Shoulders*** No 1 ☐ Yes 2 ☐ in the right shoulder 3 ☐ in the left shoulder 4 ☐ in both shoulders | **5** ***Shoulders*** No 1 ☐ Yes 2 ☐ in the right shoulder 3 ☐ in the left shoulder 4 ☐ in both shoulders | **6** ***Shoulders (both/either)*** No 1 ☐ Yes 2 ☐ |
| ***Elbows*** No 1 ☐ Yes 2 ☐ in the right elbow 3 ☐ in the left elbow 4 ☐ in both elbows | **8** ***Elbows*** No 1 ☐ Yes 2 ☐ in the right elbow 3 ☐ in the left elbow 4 ☐ in both elbows | **9** ***Elbows (both/either)*** No 1 ☐ Yes 2 ☐ |
| ***Wrists/hands*** No 1 ☐ Yes 2 ☐ in the right wrist/hand 3 ☐ in the left wrist/hand 4 ☐ in both wrists/hands | **11** ***Wrists/hands*** No 1 ☐ Yes 2 ☐ in the right wrist/hand 3 ☐ in the left wrist/hand 4 ☐ in both wrists/hands | **12** ***Wrists/hands (both/eithe*** No 1 ☐ Yes 2 ☐ |
| ***Upper back*** No 1 ☐ Yes 2 ☐ | **14** ***Upper back*** No 1 ☐ Yes 2 ☐ | **15** ***Upper back*** No 1 ☐ Yes 2 ☐ |
| ***Lower back (small of the back)*** No 1 ☐ Yes 2 ☐ | **17** ***Lower back*** No 1 ☐ Yes 2 ☐ | **18** ***Lower back*** No 1 ☐ Yes 2 ☐ |
| ***One or both hips/thighs/buttocks*** No 1 ☐ Yes 2 ☐ | **20** ***Hips/thighs/buttocks*** No 1 ☐ Yes 2 ☐ | **21** ***Hips/thighs/buttocks*** No 1 ☐ Yes 2 ☐ |
| ***One or both knees*** No 1 ☐ Yes 2 ☐ | **23** ***Knees*** No 1 ☐ Yes 2 ☐ | **24** ***Knees*** No 1 ☐ Yes 2 ☐ |
| ***One or both ankles/feet*** No 1 ☐ Yes 2 ☐ | **26** ***Ankles/feet*** No 1 ☐ Yes 2 ☐ | **27** ***Ankles/feet*** No 1 ☐ Yes 2 ☐ |

## ANNAXURE-VII

### Acceptability of *aonla* pricking machine

**Name of respondent:** **Enterprise:**

| | Yes | No |
|---|---|---|
| **Relative Advantage** | | |
| 1. The machine is extremely advantageous device for women workers (+) | | |
| 2. SMEs can afford Rs. 2500 to buy the machine (+) | | |
| 3. It is labour saving device (+) | | |
| 4. It is time saving device (+) | | |
| 5. It reduces drudgery of women workers like highly repetitive motions of upper extremities, neck and back ache (+) | | |
| 6. One can do more work with machine in comparison to manual pricking (+) | | |
| **Compatibility** | | |
| 1. The machine can be easily put to use by the women workers (+) | | |
| 2. No problem in storing machine (+) | | |
| 3. The machine doesn't suit to your requirement (+) | | |
| **Simplicity and Complexity** | | |
| 1. The machine is an easy to operate device (+) | | |
| 2. It is difficult to operate than manual pricking tools (-) | | |
| 3. It is more a problem to wash and clean the machine after its use (-) | | |
| **Satisfaction** | | |
| 1. On the basis of the triability experience you would pass on the information to the other regarding usefulness of the machine (+) | | |
| 2. The machine is useful enough for income generating activity (+) | | |
| 3. The *aonla* fruit pricked with machine have uniform number and size of pricks. | | |
| 4. The preserve prepared from machine pricked *aonla* is more appealing and tasty than preserve prepared from hand tool pricked *aonla* (+) | | |
| 5. Satisfied with working of machine (+) | | |

## ANNEXURE-VIII

**Record sheet for *aonla* pricking machine**

**Name:**

**Enterprise:**

**Interview schedule:**

**I: Safety and comfort of workers while working on machine**

1. Minor finger injuries while working on with machine: No/Yes
2. Eye aches while working on machine: Yes/No
3. Postural stress while working on machine. Low/ Moderate/High
4. Level of comfort experienced while working with machine:

| **5** | **4** | **3** | **2** | **1** |
|---|---|---|---|---|
| Extreme comfortable | Comfortable | Undecided | Discomfort | Extreme discomfortable |

**Observation sheet:**

**II**: **Economic benefits associated with use of machine**

1. Productivity of machine:
2. Time saved while working on machine:
3. Energy and cost of pricking saved while working on machine:
4. Quality of final product prepared:

## ANNEXURE-IX

**Method used for preserve preparation:**

Preserve is prepared from matured, whole or in large pieces of fruit in which sugar is impregnated till it become tender and transparent. Minimum fruit proportion in preserve should be 55 percent.

**Recipe:**

Mature *aonla* fruit…………1 kg

Sugar………………………..1.25 kg

Citric acid…………………..2-3 gm

Water………………………750 ml

**Processing technique:**

Select suitable sized mature *aonla* fruits, wash and prick with stainless steel hand tool, fork or machine. Dip pricked *aonla* in 2 percent salt solution for 1 day. Next day, take out fruit from salt solution and again dip in freshly prepared salt solution (2 %) for 24 hours after thorough washing. Continue this process for another 2 day. After this, take out *aonla* from salt solution and wash thoroughly in running water. Salt treatment is given to remove astringency of *aonla* fruit. Fruit are now dipped in 2 percent alum solution for 24 hours. Next day, fruits are again washed in running water and blanched in boiling water for 4-6 minutes. Take care that *aonla* fruit are not cracked during blanching. Now spread the blanched *aonla* fruit on a dry muslin cloth to remove any extra water present in the fruits.

Prepare sugar syrup of 40 percent concentration and dip blanched *aonla* fruit in it for 24 hours. Next day, raise the concentration of sugar syrup by adding sugar and further boiling the sugar syrup. Remove the *aonla* fruit from sugar syrup during of syrup and again dip them into sugar syrup after boiling it. Follow this process on alternate days and raise the concentration of sugar syrup upto 70 percent in 6-7 days. Now keep the *aonla* fruit dipped in sugar syrup far about a week and check the concentration of sugar syrup again after a week. If its concentration is less than 70 percent, then again boil the syrup after removing the *aonla* fruit to raise its concentration upto 70 percent. Steep *aonla* fruit in sugar syrup and fill *aonla* preserve into glass jars, seal and store in a cool and dry place for consumption in future.

**ANNEXURE-X**

**Nine point hedonic rating scale**

**Name -----------------** **Dated ------------**

**Products ----------------**

Test these samples and check how much you like or dislike each one. Use appropriate scale to show your attitude by assigning points that best describe your feelings about the sample. An honest expression of your feelings will help us.

| Sr. No. | Colour | Appearance | Aroma | Texture | Taste | Overall acceptability | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

| **Rate** | **Organoleptic score** |
|---|---|
| Like extremely | 9 |
| Like very much | 8 |
| Like moderately | 7 |
| Like slightly | 6 |
| Neither like nor dislike | 5 |
| Dislike slightly | 4 |
| Dislike moderately | 3 |
| Dislike very much | 2 |
| Dislike extremely | 1 |

## ANNEXURE-XI

**Ascorbic acid estimation:**

Ascorbic acid in the samples was estimated by using titration method.

**Reagents**

1. Metaphosphoric acid-acetic acid solution: 15 gm $HPO_3$ pellets were dissolved in 40 ml glacial acetic acid and 200 ml distilled water and diluted to 500 ml. It was rapidly filtered through filter paper into a glass stopper bottle.
2. Ascorbic acid standard solution (1 mg ascorbic acid/ml): 50 mg ascorbic acid reference standard (that has been stored in the desiccators away from direct sunlight) was weighted and transferred to 50 ml volumetric flask. It was diluted to volume immediately (before use) with metaphosphoric acetic acid solution.
3. Indophenol standard solution: Fifty mg 2,6, dicholorophenol sodium salt ( that has been stored in the desiccator) was dissolved in 50 ml distilled water , to which 42 mg sodium bicarbonate had been added with dye dissolved; it was diluted to 200 ml with distilled water and was filtered through Whatman # 1 into amber glass stopper bottle. This was kept stoppered and away from direct sunlight into refrigerator.

**Extraction**

To 5 gm of sample, 25 mg of phosphoric acid solution was added. The sample was made to a fine pulp in pestle and mortar until the suspension appeared one, mixed well and the volume was made to 100 ml with metaphosphoric acetic acid solution. Filter rapidly through Whatman # 1.

**Estimation**

2 ml aliquot of ascorbic acid standard solution was taken in triplicate in each of the three 50 ml conical flasks containing 5 ml metaphosphoric acetic acid solution. These standard samples were titrated rapidly with indophenol solution from a microburette until light, but distinct rose pink color persist at least for 5 seconds. For the sample. 5 ml metaphosphoric acetic acid was added to each of 2 ml of sample aliquots and titrated with indophenol solution as for blank and standard.

Ascorbic acid content (mg/100 g) was calculated as follows:

**Calculation**

$$\frac{Y-B}{X-B} \times \frac{V}{W} \times 100$$

Where:

Y = Volume of dye solution used against sample aliquot

B = Volume of dye solution used against blank

X = Volume of dye solution used against standard

V = Volume of the aliquot made

W = weight of the sample

**Annexure XII**

**ANTHROPOMETRIC DATA OF WOMEN WORKERS**

**IN**

***AONLA* PROCESSING ENTERPRISES**

**Name:**
**Age**:
**Enterprise:**

| S. No. | Body parts | Measurements |
|---|---|---|
| **Standing anthropometric measurements (cm)** | | |
| 1 | Weight | |
| 2 | Height | |
| 3 | Elbow height | |
| **Sitting anthropometric measurements (cm)** | | |
| S. No. | Measurements | |
| 1 | Sitting height | |
| | Normal | |
| | Erect | |
| 2 | Hip breadth | |
| 3 | Knee height | |
| 4 | Popliteal height | |
| 5 | Buttock -popliteal length | |
| 6 | Buttock- knee length | |
| **Hand and Arm anthropometric measurements (cm)** | | |
| 1 | Hand breadth | |
| 2 | Hand breadth across thumb | |
| 3 | Hand length | |
| 4 | Arm length | |
| | Upper arm | |
| | Lower arm | |
| **Normal and Maximum Reaches** | | |
| 1 | Normal reach in horizontal plane | |
| | Right hand | |
| | Left hand | |
| 2 | Maximum Reach in Horizontal plane | |
| | Right hand | |
| | Left hand | |

# ABSTRACT

| | | |
|---|---|---|
| **Tile of thesis** | : | Ergonomic evaluation of conventional and improved methods of *aonla* pricking |
| **Full name of the degree holder** | : | Arpana Rai |
| **Admission Number** | : | 2010HS161M |
| **Title of degree** | : | Master of Science |
| **Name and address of Major Advisor** | : | Dr. Sudesh Gandhi<br>Professor and Head,<br>Deptt. of Family Resource Management,COHS<br>CCS HAU, Hisar – 125004 |
| **Degree awarding university** | : | CCS Haryana Agriculture University Hisar |
| **Year of award of degree** | : | 2012 |
| **Major subject** | : | Family Resource Management |
| **Total number of pages in thesis** | : | 85 + iv + XV |
| **Number of words in abstract** | : | Approximately 519 words |

*Key words: SMEs, workstation, RSM, WISE*

Indian food preservation industry is predominantly occupied with processed *aonla* products especially *aonla* preserve. Women are the vital and most productive workers in preserve making SMEs and do the most monotonous job of pricking individual *aonla* fruit for preserve making. Till date, the pricking of *aonla* fruits in these enterprises is done manually employing poorly designed hand tools thus, making the pricking task very tiresome and time consuming for workers resulting into lowered productivity. Therefore, a hand operated *aonla* pricking machine developed by AICRP on PHT, CCSHAU, Hisar was ergonomically tested with women workers. A study was conducted on ergonomic evaluation of conventional and improved methods of *aonla* pricking which was carried out in 3 phases *i.e.* field survey to study working conditions and work profile of workers in selected four preserve making units, experimental work to conduct ergonomic evaluation of conventional (fork and hand tool) and improved (pricking machine) methods of *aonla* pricking, user's acceptability of machine, organoleptic evaluation of preserve prepared. Thereafter, a sit-stand workstation was developed using RSM and improvements were suggested for preserve making SMEs as per WISE methodology. The results revealed that working conditions, processing tools and techniques were not satisfactory in all the units. The workers were doing pricking by using poorly designed hand tools in awkward postures and there were no defined workstations in all the units. Ergonomic evaluation of all the tools in various postures in terms of physiological, biomechanical and psycho-physical parameters with 15 women workers selected from four enterprises revealed that physiological parameters while working with all the tools were within the acceptable limits for women workers. The HR showed maximum increase while pricking with machine in squatting posture (90 beats.min$^{-1}$). However, biomechanical and psycho-physical parameters were higher while working with conventional tools as compared to the machine. The grip fatigue was found to be maximum with fork in squatting posture (26 %). The reason for this was attributed to use of poorly designed conventional tools and lack of proper workstation. Machine was found highly acceptable by the users due to more safety, comfort and higher economic benefits while working. The preserve prepared with machine pricked *aonla* obtained highest sensory score (8.5), highest ascorbic acid content (150 mg/100 gm of fresh fruit) and least water activity (0.53). A fully adjustable ergonomically designed workstation was developed and used for the experiment. RSM was used to find out the best combination of posture (200 mm-600 mm-1000 mm), duration of the pricking activity (1hr-2 hr- 3 hr) and light (100 lux-300 lux -500 lux) while working with conventional tools and machine that has yielded most favorable results. The most desirable combinations obtained were 500 mm height +500 lux light + 2 hr time with conventional tools in sitting posture and 200 mm height+300 lux light+1.45 hr time and 1000 mm height+300 lux light+1.30 hr time with machine in low stool posture and standing posture respectively. Improvements were also suggested for preserve making SMEs using WISE methodology concerning with material storage and handling, workstation design and work environment. This all has resulted into reducing drudgery of women workers involved in preserve making activity.

**MAJOR ADVISOR** **DEGREE HOLDER**

**HEAD OF THE DEPARTMENT**

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**Papers published:**

**a.** Rai, A.; Gandhi, S & Sharma, D K. 2012. Ergonomic Evaluation of Conventional and Improved Methods of *Aonla* Pricking with Women Workers. Work, 41 , 1239-1245

**b.** Rai ,A.; Gandhi S.; Kumar N.; Sharma D K; Garg M K. 2012. Ergonomic Intervention in *Aonla* Pricking Operation during Preserve Preparation in Food Processing Industries. Work, 41, 401-405.

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