THERMAL EFFICIENCY AND QUALITY OF COOKED FOOD: EVALUATION OF COOKWARE MATERIALS

Thesis

Submitted to the Punjab Agricultural University
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FAMILY RESOURCE MANAGEMENT
(Minor Subject: Extension Education and Communication Management)

By

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CERTIFICATE I

This is to certify that the thesis entitled, **"Thermal efficiency and quality of cooked food: Evaluation of cookware materials"** submitted for the degree of **Master of Science,** in the subject of **Family Resource Management** (Minor subject: **Extension Education and Communication Management**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Alakuntla Priyanka (L-2018-HSc-333-M)** under my supervision and that no part of thesis 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 the thesis entitled, **"Thermal efficiency and quality of cooked food: Evaluation of cookware materials"** submitted by **Alakuntla Priyanka (L-2018-HSc-333-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science,** in the subject of **Family Resource Management** (Minor subject: **Extension Education and Communication Management**) has been approved by the Student's Advisory Committee along with External Examiner after an oral examination on the same.

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ABSTRACT

The present study entitled "Thermal efficiency and quality of cooked food: Evaluation of cookware materials" was undertaken with an aim to find out the commonly available cookware materials for surface cooking, to study the thermal efficiency of selected cookware materials as well as to assess the extent of microbial and toxic contents in food cooked in selected cookware. The study was conducted in three parts i.e., market survey, household survey and laboratory experiments. Market and household survey was conducted in different locations of Ludhiana city. For laboratory experiments, six commonly used cookware materials namely non-stick, stainless steel, nonstick with ceramic coating, nonstick with granite coating, hard anodized and clay pans were selected and two standardized recipes namely *jeera* rice and potato with fenugreek leaves vegetable (dry) were selected. The results revealed that hard anodized was best in terms of heat conductivity followed by non-stick with ceramic coating pan; whereas, stainless steel followed by nonstick with ceramic coating pan were best in terms of heat retention. Lowest fuel consumption was observed in stainless steel pan followed by hard anodized and nonstick with ceramic coating pan due to larger diameter. Non-stick with ceramic coating pan followed by non-stick pan were found best in terms of organoleptic evaluation. The heavy metal analysis showed that chromium content in all the selected cookware was higher than permissible limit (0.05-0.20 mg/day) in both the cooked recipes. Nonstick with ceramic coating recorded lowest chromium content i.e. 0.28 and 0.80 mg immediately after cooking and 0.45 and 0.94 mg after one hour of cooking in *jeera* rice and potatoes with fenugreek leaves vegetable (dry) respectively. Arsenic and cadmium contents were found to be within permissible limits. Nickel and lead were found minimum in nonstick with ceramic coating and clay pan when compared with all other selected cookware materials. No microbial contamination was observed in selected cookware materials.

Keywords: Heat conductivity, heat retention, fuel consumption, organoleptic evaluation, moisture content, heavy metals, microbial analysis

Signature of Major Advisor | **Signature of the Student**

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ਮੌਜੂਦਾ ਅਧਿਐਨ "ਭੋਜਨ ਪਕਾਉਣ ਵਾਲੇ ਬਰਤਨਾਂ ਦੀ ਥਰਮਲ ਕੁਸ਼ਲਤਾ ਅਤੇ ਪਕਾਏ ਹੋਏ ਭੋਜਨ ਦੀ ਗੁਣਵੱਤਾ ਦਾ ਮੁਲਾਂਕਣ" ਸਿਰਲੇਖ ਅਧੀਨ ਭੋਜਨ ਪਕਾਉਣ ਲਈ ਆਮ ਮਿਲਣ ਵਾਲੇ ਬਰਤਨਾਂ ਦੀ ਉਪਲਬਧਤਾ ਦਾ ਪਤਾ ਲਗਾਉਣ, ਅਧਿਐਨ ਲਈ ਚੁਣੇ ਗਏ ਭੋਜਨ ਪਕਾਉਣ ਦੇ ਬਰਤਨਾਂ ਦੀ ਥਰਮਲ ਕੁਸ਼ਲਤਾ ਅਤੇ ਇਹਨਾਂ ਵਿੱਚ ਬਣਾਏ ਗਏ ਭੋਜਨ ਵਿੱਚ ਸੂਖਮ ਜੀਵਾਨੂੰ ਅਤੇ ਧਾਤਾਂ ਦੇ ਜ਼ਹਿਰੀਲੇਪਣ ਦੀ ਹੱਦ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਦੇ ਮਕਸਦ ਨਾਲ ਕੀਤਾ ਗਿਆ। ਇਹ ਅਧਿਐਨ ਦੌਰਾਨ ਮਾਰਕੀਟ ਸਰਵੇਖਣ, ਘਰਾਂ ਦਾ ਸਰਵੇਖਣ ਅਤੇ ਪ੍ਰਯੋਗਸ਼ਾਲਾ ਤਜ਼ਰਬੇ ਕੀਤੇ ਗਏ। ਲੁਧਿਆਣਾ ਸ਼ਹਿਰ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਹਿੱਸਿਆਂ ਵਿੱਚ ਮਾਰਕੀਟ ਅਤੇ ਘਰਾਂ ਦਾ ਸਰਵੇਖਣ ਕੀਤਾ ਗਿਆ। ਪ੍ਰਯੋਗਸ਼ਾਲਾ ਤਜ਼ਰਬਿਆਂ ਦੌਰਾਨ, ਖਾਣਾ ਪਕਾਉਣ ਲਈ ਵਰਤੇ ਜਾਂਦੇ ਛੇ ਤਰ੍ਹਾਂ ਦੇ ਭੋਜਨ ਪਕਾਉਣ ਵਾਲੇ ਬਰਤਨਾਂ ਭਾਵ ਨਾਨ-ਸਟਿਕ, ਸਟੇਨਲੈਸ ਸਟੀਲ, ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲੀ ਨਾਨ ਸਟਿੱਕ, ਗ੍ਰੇਨਾਈਟ ਕੋਟਿੰਗ ਵਾਲੀ ਨਾਨ ਸਟਿਕ, ਹਾਰਡ ਐਨੋਡਾਇਜ਼ਡ ਅਤੇ ਕਲੇਅ ਪੇਨ ਵਿੱਚ ਦੋ ਵਿਅੰਜਨ - ਜੀਰੇ ਵਾਲੇ ਚੌਲ ਅਤੇ ਮੇਥੀ ਆਲੂ ਦੀ ਸਬਜ਼ੀ ਬਣਾਈ ਗਈ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਹਾਰਡ ਐਨੋਡਾਇਜ਼ਡ ਦੀ ਥਰਮਲ ਸੰਚਾਲਕਤਾ ਸਭ ਤੋਂ ਵਧੀਆ ਸੀ ਅਤੇ ਇਸ ਮਗਰੋਂ ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲੇ ਨਾਨ-ਸਟਿਕ ਪੈਨ ਦੀ ਉਸ਼ਮੀ ਸੰਚਾਲਕਤਾ ਵਧੀਆ ਸੀ; ਜਦੋਂਕਿ ਗਰਮੀ ਨੂੰ ਬਰਕਰਾਰ ਰੱਖਣ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਸਟੇਨਲੈਸ ਸਟੀਲ ਅਤੇ ਇਸ ਮਗਰੋਂ ਸੀਰੇਮਿੰਕ ਕੋਟਿੰਗ ਵਾਲੇ ਨਾਨ ਸਟਿੱਕ ਪੈਨ ਵਧੀਆ ਸਨ। ਜ਼ਿਆਦਾ ਵਿਆਸ ਹੋਣ ਕਾਰਨ ਸਟੈਨਲੈਸ ਸਟੀਪ ਪੈਨ ਵਿੱਚ ਖਾਣਾ ਬਨਾਉਣ ਨਾਲ ਇੰਧਣ ਦੀ ਘੱਟ ਖਪਤ ਹੋਈ ਅਤੇ ਮਗਰੋਂ ਹਾਰਡ ਐਨੋਡਾਇਜ਼ਡ ਅਤੇ ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲਾ ਨਾਨ ਸਟਿਕ ਪੈਨ ਵਿੱਚ ਇੰਧਣ ਦੀ ਘੱਟ ਖਪਤ ਹੋਈ। ਆਰਗੈਨੋਲੇਪਟਿਕ ਮੁਲਾਂਕਣ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲੇ ਨਾਨ ਸਟਿੱਕ ਪੈਨ ਅਤੇ ਇਸ ਮਗਰੋਂ ਨਾਨ ਸਟਿਕ ਪੈਨ ਵਧੀਆ ਸਨ। ਭਾਰੀਆਂ ਧਾਤਾਂ ਦੇ ਜ਼ਹਿਰੀਲੇਪਣ ਦੇ ਮੁਲਾਂਕਣ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਖਾਣਾ ਬਨਾਉਣ ਲਈ ਵਰਤੇ ਗਏ ਛੇ ਤਰ੍ਹਾਂ ਦੇ ਬਰਤਨਾਂ ਵਿੱਚ ਪਕਾਏ ਗਏ ਦੋਨਾਂ ਵਿਅੰਜਨਾਂ ਵਿੱਚ ਭਾਰੀਆਂ ਧਾਤਾਂ ਦੀ ਮਾਤਰਾ, ਨਿਰਧਾਰਤ ਮਾਤਾਰਾ (0.05-0.20 ਮਿ.ਗ੍ਰਾ/ਦਿਨ) ਤੋਂ ਵਧੇਰੇ ਸੀ। ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲੇ ਨਾਨ ਸਟਿਕ ਵਿੱਚ ਬਣਾਏ ਗਏ ਜੀਰੇ ਵਾਲੇ ਚੌਲਾਂ ਅਤੇ ਮੈਥੀ ਆਲੂ ਵਿੱਚ ਪਕਾਉਣ ਤੋਂ ਤੁਰੰਤ ਬਾਅਦ ਕ੍ਰੋਮੀਅਮ ਦੀ ਮਾਤਰਾ 0.28 ਅਤੇ 0.80 ਮਿ.ਗ੍ਰਾ. ਸੀ ਅਤੇ ਪਕਾਉਣ ਦੇ ਇੱਕ ਘੰਟੇ ਮਗਰੋਂ ਇਹਨਾਂ ਪਕਵਾਨਾਂ ਵਿੱਚ ਕ੍ਰੋਮੀਅਮ ਦੀ ਮਾਤਰਾ 0.45 ਅਤੇ 0.94 ਮਿ.ਗ੍ਰਾ. ਸੀ। ਹਰ ਤਰ੍ਹਾਂ ਦੇ ਬਰਤਨ ਵਿੱਚ ਪਕਾਏ ਗਏ ਭੋਜਨ ਵਿੱਚ ਆਰਸੇਨਿਕ ਅਤੇ ਕੈਡਮੀਅਮ ਦੀ ਮਾਤਰਾ ਨਿਰਧਾਰਤ ਹੱਦ ਵਿੱਚ ਹੀ ਸੀ। ਬਾਕੀ ਸਾਰੇ ਬਰਤਨਾਂ ਦੇ ਮੁਕਾਬਲੇ ਸੀਰੇਮਿਕ ਕੋਟਿੰਗ ਵਾਲੇ ਨਾਨ ਸਟਿਕ ਅਤੇ ਕਲੇਅ ਪੈਨ ਵਿੱਚ ਪਕਾਏ ਗਏ ਪਕਵਾਨਾਂ ਵਿੱਚ ਨਿਕਲ ਅਤੇ ਲੈਡ ਦੀ ਮਾਤਰਾ ਘੱਟ ਸੀ। ਭੋਜਨ ਪਕਾਉਣ ਲਈ ਵਰਤੇ ਗਏ ਸਾਰੇ ਬਰਤਨਾਂ ਵਿੱਚ ਬਣਾਏ ਗਏ ਭੋਜਨ ਦੇ ਨਮੂਨਿਆਂ ਵਿੱਚ ਸੂਖਮ-ਜੀਵਾਨੂੰ ਦਾ ਦੂਸ਼ਣ ਨਹੀਂ ਵੇਖਿਆ ਗਿਆ।

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(ਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ)

(ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ)

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CHAPTER I

INTRODUCTION

As a consumer, we have several expectations on food available which includes safe, hygienic, nutritive and wholesome with right nutritional content, protected from microbial contamination, intoxication and adulteration. Cooking is an inevitable part of our daily life. Home without cookware is un-imaginary. Technological advances during industrialization brought major changes in the kitchenware. The adoption of the new cookware was slow due to the high cost. Quality and innovative cookware materials with high quality finishes are available which are able to meet the consumer needs and demands.

Now-a-days, people are more conscious about eating healthy. However, not every individual knows that the cookware used to prepare the food is almost as significant as the food itself. Proper selection of commonly used cookware materials can be of great help in resource saving as well as in contributing health of the family (Sidhu *et al* 2007). Cookware selected for cooking should be durable, simple in design and of suitable size and shape. Kitchen is one of the places which deal with the phenomenon of heat conduction and heat retention in cookware materials. Heat conductivity is how fast the pan will heat up (Kadam and Shete, 2017). Heat retention refers to the amount of heat a pan can store overtime. The nature of cookware materials and cooking process can increase trace metal levels in food (Anderson *et al* 1992; Ebong *et al* 2006). From time to time, concern is expressed over the possibility of pick-up of metals and their compounds from cookware used in the cooking of food (Rasmussen 1983), and their possible adverse effects on human health and food quality. If the cookware is toxic, then even the healthiest diet can result in health complications.

The purchase of cookware were influenced by parameters like gender, income, the housing market boom of the past decade, advertising and promotion, cookware composition and innovative technological designs. The food standard regulation act and tables of food composition are of limited assistance to the toxicologist, investigating dietary intake of metals by individual because during the cooking of food in metallic cookware, significant quantities of toxic elements may leach out and increase the uptake metal above the admissible daily intake (ADI) values even in well regulated and hygienic household. In India, food habits i.e. component of diet, type of cookware and methods of preparation of food are different from those of developed countries. Hence, there is need to evaluate the leaching behaviour of constituent metals from cookware in a wide variety of cooked food materials.

Numerous cookware materials are available in the market. Majority of cookware materials are either made up of different metals alone or in combination. The material properties of cookware, such as hydrophobicity, surface roughness and conductivity can impact the taste of a dish dramatically. The interactions between food and cookware are very much dependent on the material that the cookware is made of. The different cookware materials like, aluminium, copper, non-stick, non-stick with ceramic coating, non-stick with granite coating, stainless steel, stainless steel with copper base, stainless steel- Tri ply, hindalium, hard anodized, earthenware, cast iron, brass, aluminium with marble coating are available in the market.

Every metal has its own distinct characteristics with respect to heat conductivity, heat retention, time taken and fuel consumption. Metal elements of these cookware materials may get dissolved in cooking when it comes in contact with food affecting the mineral contents of the food. These metal elements can have either positive or negative effect depending on the type and amount of metal used (Thakral and Sangwan, 1996). For example, the ease to use and clean, make the non-stick cookware popular but usage of non-stick cookware is resulting in increased risk of certain types of cancer. The perflourooctanoic acid (PFOA), present in non-stick cookware gets released if temperatures are too high. Copper cookware materials are great conductors of heat which are commonly lined with tin or stainless steel. Usage of unlined copper cookware is warned by the FDA (Food and Drug Administration) since the metal toxicity can leach into acidic food, causing copper toxicity. Enamelled iron, steel, and stainless steel are unlikely to cause potentially hazardous levels of toxic material to enter into food. Stainless steel is an alloy of iron and other metals with low heat conductivity. It is durable and also resistant to rust and corrosion (Amidor, 2014). On the other hand, cast iron is fairly good conductor of heat and due to high thermal mass it holds the heat well. It is comparatively inexpensive, heavy and is difficult to keep looking attractive in appearance. The most important thing regarding the use of iron cookware is that it could increase the iron intake of women and their families by cooking food in them. Inexpensive aluminium cookware is widely used throughout the developing world. Much of this cookware is locally made, uncoated and not ionised. Aluminium cookware materials are made up of cast aluminium which reacts with acidic food. Leafy vegetable cooked in aluminium pans are prone to leach the metal from the cookware and it has been implicated as a contributory cause of alzheimer's disease (Anonymous, 2003).

Traditionally, Indian households are acknowledged to have cooked in earthen pots. However in urban families, paucity of time and maintenance of such materials have regularly led human beings to look for modern-day alternatives like non-stick cookware, aluminium and steel over clay cookware. The advantages of earthen cookware includes moisture absorption due to their porous nature, letting heat circulate slowly through the food being cooked, imparting required minerals that encompass magnesium, calcium, iron and phosphorus (Basu, 2017). Moreover, clay pan blend properly with acidic food due to their alkaline in nature which creates a balance (Walia, 2017). Two chief advantages of clay pot cooking are its alkaline nature and circulation of heat and moisture during cooking (Christensen, 2011). Since times immemorial most of the cultures have had a tradition of using clay pan for cooking. Modernization has certainly made the lifestyles smooth and cosier than it was centuries ago. It has furnished numerous modern tools and techniques to use for various purposes along with modern kitchen cookware used for daily cooking. However, there is a severe hassle with the modern cookware. Non-stick cookware and different steel pans break most of the nutrients in food.

The earthenware can not only preserve and even can increase the nutritional value of the food (Bodke, 2016). Some glazes on pottery materials that have been wrongly mixed or fired have caused potentially harmful amounts of the heavy metals such as lead and cadmium to migrate into acid foods that have been cooked or stored in these cookware. This is not normally a problem because modern methods of glazing produce resistant products.

Toxicity of heavy metals is a serious problem through-out the world. Consumption of heavy metals through cookware acts as a slow poison in human body. Heavy metals are generally referred to as those metals which possess a specific density of more than $5 g/cm^3$. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long term exposure of some metals may even cause cancer (Jarup, 2003). Metals are particularly toxic to the sensitive, rapidly developing systems of foetuses, infants and young children. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioural problems such as aggressiveness and hyperactivity. At higher doses, heavy metals can cause irreversible brain damage. Children may receive higher doses of metals from food than adults, since they consume more food for their body weight than adults (Thirulogachandar *et al* 2014).

Acute toxicity arises from competitive interaction with 5 major essential elements calcium, cobalt, copper, iron and zinc. Intake of metals like nickel and chromium cause paralysis, gastroenteritis, cancer and heart failure while cadmium is known to cause dysfunctioning of kidneys in humans (Prasad *et al* 1995). Ingested cadmium is poorly absorbed probably at about 3-8 per cent in man, but absorbed cadmium is retained for long periods by the body. An excess of copper in the body can lead to arthritis, insanity and schizophrenia. Some elements, such as lead and cadmium are highly toxic and should be avoided at all costs. Lead toxicity leads to deficiency of iron, riboflavin and nicotinic acid. It also affects haemoglobin levels in human body. Predominance of malnutrition further aggravates the problem and multiply the risks associated with heavy metals on the health of children (NIN, 1997). Similarly, iron is essential to produce red blood cells, but large amounts can be poisonous.

Due to availability of wide variety of cookware materials for surface cooking and considering the harmful/toxic effect of different metals used for cooking, the present study entitled "Thermal efficiency and quality of cooked food: Evaluation of cookware material" was planned with the following specific objectives:-

1. To find out commonly available cookware materials for surface cooking.

2. To study the thermal efficiency of selected cookware materials.

3. To assess the extent of microbial and toxic contents in food cooked in selected cookware.

Limitations of the study

1. Most of the information in the interview schedule was collected on the basis of expressed opinions of the shopkeepers and the homemakers, so some biasness may be expected.
2. The study is limited only to the most commonly used cookware materials
3. Only two frequently cooked recipes by the families, i.e., *jeera* rice and potatoes with fenugreek leaves vegetable (dry) were cooked for conducting experiments due to limitation of resources.
4. The study is limited to only one type of heating unit, i.e., gas stove.
5. The results of this study will be applicable only to those families who use these cookware materials.

CHAPTER-II

REVIEW OF LITERATURE

To formulate the problem precisely, it seems essential to give brief review of researches which are related directly or indirectly to the present study, entitled “Thermal efficiency and quality of cooked food: Evaluation of cookware materials”.

The chapter contains researches, which have been conducted in India and abroad related to the present study. A brief review of these studies has been organised and reported under following sub-heads;

2.1 Cookware materials for surface cooking

2.2 Thermal efficiency of cookware materials

2.3 Microbial and toxic contents in food cooked in different cookware materials

2.1 Cookware materials for surface cookware

Phelps (1986) emphasised that pottery used for cookware is typically glazed to produce a water-tight and a non-porous surface. The glass-like glaze of exact earthenware and ceramics is produced by way of coating the floor with a carefully prepared frit and heating it to an excessive temperature in a kiln. Glazes are applied to clay-based cookware to provide a shiny, commonly smooth surface and seal of the clay.

Flint and Packirisamy (1995) examined Systemic nickel: the contribution made by stainless-steel cooking utensils. An extensive programme on cooking operations showed that 19 Cr/9 Ni stainless-steel utensils to nickel in the diet is negligible. The amount of nickel (0 to 8 µg) found in utensils was less than that of 1 square of a bitter-sweet chocolate bar. Foods prepared in new pans with acid fruits shows high amount of nickel which is approximately 1/5 of the normal daily intake for the average person (ca. 200µg) this does not occur in repeated usage and pan has completely cleaned by abrasion. This indicates that greater amount of nickel was released in new pans and reduces after the repeated usage.

Kolarik (2006) studied Cookware sustainability. Key to the cookware sustainability is its durability. Manufacturing of all cookware creates some poor environmental effect, from mining and refining uncooked substances till packaging and transport. The best way to reduce such impact is by investigating the cookware. Light-weight aluminium cookware is the easiest one to carry across the kitchen, but aluminium isn't long lasting. Cast iron is more durable, because it lasts for generations with the proper care. Stainless steel is likewise exceedingly durable, since it is resistant to scratching, corrosion, rust, and denting. Enamelled cast iron requires lesser care than regular, although there is chance of rusting if the enamel coating erodes. Be conscious that the cheap imported enamelled cookware or glaze on vintage can leach lead into the food.

Cheng (2007) conducted a study on laminated cookware with protected edge. A more than one layer clad article of cookware has an upper rim wherein the internal and outer layers of the cladding, generally chrome steel, are joined together by a weld that covers and protects the one or more layers. The inner layers are alternatively at least one of the copper and aluminium, or combinations of the same.

Seaman (2009) performed a study on wholesome cookware. Blending metallic with chromium and nickel (18/10 has 10 percentage nickel) produces a corrosion resistant metal that is both difficult sporting and smooth to clean. Stainless steel cookware is considered one of the exceptional and safest selections in cookware. Cookware made from simple aluminium is light-weight, thermally responsive and low price. Aluminium is known to react with the metallic forming aluminium salts associated with Alzheimer’s ailment and impaired visible motor coordination; moreover there is no proven evidence. Most of the cookware offered nowadays is made from aluminium. Copper pans are often covered with steel that stops the copper from coming into touch with meals. Small quantities of the coating can be dissolved by food, in particular acidic meals, when cooked or stored for long duration. Stainless steel/copper cookware is considered some of the fine and safest alternatives in cookware.

Pinola (2012) suggested avoid cooking mistakes: use of proper pans and pots for cooking. While cooking acidic foods, non-reactive pans are to be used. During preparation of acidic foods along with lemons, tomatoes or cranberries, ensure to apply pans which are non reactive in nature, such as glass, stainless steel or enamel-coated. Reactive pans, including cast iron or aluminium can impart an off flavour or off shade in acidic foods. Non-stick cookware is used to cook less fat contents food. Non-stick cookware is an exquisite since it requires less oil. Sensitive food, consisting of eggs or fish, won't wreck apart or stick to the pan. While cooking in a non-stick cookware, use non-stick-safe cookware, along with a wooden spoon or heatproof spatula. The non-stick surface gets damaged by metal spoons. Cook over excessive heat or heating an empty cookware is avoided due to the fact that the non-stick coating may gets destroyed at excessive temperatures and release potentially toxic fumes. As an alternative to conventional non-stick cookware, look for pans traded under names like "green cookware" or "eco-friendly cookware" which can be made of non-stick coating which is resistant to excessive heat. The best alternative to non-stick cookware for most of the recipes is cast-iron skillet.

Mittal *et al* (2014) focussed on home makers regarding the knowledge about base material of cooking utensils. Factors like proper selection, arrangement, use and care gives the satisfaction to home maker without any physical and mental trauma. Interest of home maker in the selection of cookware mainly depends on the metals that they are made of. The dual responsibility of them in and outside the home has greater pressure on productivity and work quality. The selection of right metal with appropriate size has become major issue for homemakers. Study revealed that the rural and urban respondents were aware of hindalium and aluminium metal that was used for construction of utensils for Indian cooking. Hindalium was the most commonly used followed by aluminium, stainless steel whereas, earthenware, chinaware and stoneware were least used materials. Aluminium, hindalium and stainless steel were easy to clean and were durable.

Trivedi *et al* (2017) reported the frequency of the use of cookware made from metals such as steel, aluminium, non-stick, copper coated and brass. The analysis indicated that 30.00 per cent of the families used steel, 24.00 per cent used aluminium and 13.00 per cent used copper lined on daily basis. Frequency of use of non-stick was 11.00 per cent and brass was never used by 22.00 per cent of the families. To cook food 97.00 per cent of the respondents used gas stove and only 3.00 per cent used electric stove.

Paranjape and kulkarni (2018) conducted a comparative study on foods prepared in aluminium pot and unglazed earthen clay pot and their storage stability. Traditionally used cooking vessels were unglazed or glazed pots whereas, in modern life style mostly steel kadai/pot, non-stick cookware, aluminium vessels etc. were used. Food cooked in unglazed earthen pot has more shelf life stability than others which was analysed by Total Plate Count (TPC).

Dimoula *et al* (2019) conducted experimental investigation of ceramic technology and plant food cooking in Neolithic northern Greece which reveals cooking pottery technology and operations through series of experiments. The first stage focuses on experimental manufacture of three types of cooking pots, following the Neolithic techniques, from raw material processing to firing. In the second stage cooking performances, using structures and fuel of pots were analyzed. Moreover, experimental cooking provided insight to the relations between the different participant parts, highlighting the pivotal relation of cooking pots to fuel and different cooking modes. This pilot study aspires to endorse ceramicists to refine protocols for future experiments and analyses on cooking technologies.

Khan and Banerjee (2020) studied revitalizing ancient Indian clay utensils and its impact on health. The food has a great impact on our mind. Combining, mixing and heating of ingredients were core for cooking. The heating ingredients depend on utensils used and type of heating method. For cooking earlier charcoal, clay stove were used, later kerosene stove, gas stove, microwave etc., were used. In Ancient times, utensils used were metals like cast iron, brass, copper or clay. Most important is the benefits of those utensils in preserving the nutritional value of food. Clay utensils preserve all the nutrients as compared to pressure cooker, steel. Cast iron utensils have a great role in increasing iron content of food specially in acidic food whereas copper improves collagen in the food. Brass enhances the immunity power of human by preserving the water. Similarly, silver has an effect on calming the mood disorder but its price is high and usage was low. The usage of old age cooking utensils improves the health of the individuals and it provides employment for clay potters, which will lead to one step ahead in developing nation's economy.

2.2 Thermal efficiency of cookware materials

Nagi and Mann (1987) performed a comparative study of cooking utensils and various heating appliances to know about the fuel consumption and efficient cooking, six pulses were cooked in two different types of brass patilas on three different cooking units. The cooking time for pulses in round-bottomed patilas was more than flat bottomed ones and cooking time was more for gas stove but the price was low.

Martin *et al* (1990) carried out the test to examine the interaction between container material and energy source in surface cooking operations like surface cooking which is determined through velocity of heating, uniform heating and heat retention. Energy sources were a traditional electric coil; conventional fuel burner; and an electric resistance heater, each underneath glass ceramic; and a solid electric element. Cookware of thin and heavy-gauge stainless steel with a thick aluminium heat core and glass ceramic was blended with each of the energy sources to finish a cooking system. Heavy gauge aluminium and heavy gauge stainless steel with a thick aluminium heat core produced the maximum even browning of crepes in all cooking systems. Irrespective of the cookware used, gas burner, and conventional electric coil boiled water quicker than did the alternative energy sources, even as the solid element and the electric resistance coil beneath glass-ceramic retained more heat.

Minakshi (1991) focussed on cooking efficiency of selected frying pans and concluded that two different aluminium frying pans had maximum heat conductivity (291^0C and 290^0C) and minimum of fuel consumption i.e. 1.86 and 1.87 gm/min. but had low heat retention with temperature declining up to 160^0C in 20 minutes. It also had low palatability scores. It took more time for cleaning i.e. 1.08 and 1.10 minutes for the two aluminium pans. Among the other selected frying pans, the one with non-stick finish had maximum heat retention (138 and 140^0C for the two non-stick pans). It took more time for cleaning and was costly which was best for high income group. For low-income group hindalium frying pans which are not very costly, had more heat retention (130 and 128^0C for both the hindalium pans) and high scores for palatability as compared to aluminium, are best to be used in terms of efficiency.

Accominotti *et al* (1998) emphasized on contribution to chromium and nickel enrichment during cooking of foods in stainless steel utensils. Ingestion of nickel causes dermatitis to those who were sensitive to nickel, chromium (Cr VI) is the 2nd allergen, followed by nickel. Stainless steel is widely used in home cookware. In a study nickel and chromium levels were determined by atomic absorption spectromeTri in 11 habitual menus cooked in different grades of stainless steel cookware. There was difference in nickel and chromium intake depending on the menu, and a significant difference between the glass and stainless steel saucepans, but this was very low compared with the levels of nickel and chromium contained in the menus; mean intakes of these elements were under the tolerable daily intake (TDI) recommended by the WHO. Hence, there is no advantage for nickel-sensitive patients in switching to materials other than stainless steel, provided that this is of good quality.

Datta (1998) reported that stainless steel cookware with copper base was best in terms of heat conductivity and heat retention properties whereas, cooking time and fuel consumption were found to be best in case of aluminium skillet but it was poor with regard to its cleaning time and quality. Non-stick cookware was found to be equally good in terms of functional design.

Bakhshi *et al* (2004) conducted a study to evaluate the efficiency of most and frequently available and used cookware for household cooking. Laboratory experiments were conducted on the seven selected cookware namely: brass, aluminium, hindalium, non-stick, satilon, stainless steel cookware with copper base. Results revealed that heat conductivity and heat retention properties were more for stainless steel cookware with copper base. The consumption of fuel was best in case of aluminium cookware. Compared to non-stick cookware, stainless steel cookware with copper bottom was best in regards to all aspects.

Natarajan *et al* (2008) studied the use of vegetable oil as fuel to improve the efficiency of cooking stove where an attempt was made to use waste vegetable oil as a fuel for a cooking stove where kerosene stove was modified for use with vegetable oil as fuel. The efficiency of the stove using vegetable oil as fuel was high as 48.9 percent as compared to conventional stove which was 34.9 per cent when a flat copper bottom vessel was used along with other vessels was also observed.

Naphon (2014) studied thermal efficiency enhancement of domestic cooking pots by water boiling test (WBT) which were fabricated from aluminium and stainless steel with different sizes of 20, 22, 24 cm. The tests were done on LPG gas stove with 2/3rd water capacity at the atmospheric pressure. The tests were monitored by using parameters like water temperature, pot surface temperature, exit flame temperature and LPG consumption at the several times by boiling point temperature. The results obtained were compared with standard cooking pots, which revealed that modified cooking pot required 15-20% less energy than the standard cooking pot to bring water to boiling. Modified cooking pots were efficient design to enhance the performance of domestic cooking pots.

Sedighi *et al* (2017) focussed on material dependence of temperature distribution in multi-layer multi-metal cookware. Laminated structure is becoming more popular but it lacks the scientific research to evaluate its pros and cons, to know its functions. A numerical model with temperature-dependent properties was performed to know the layer dependence of temperature distribution in multi-layer multi-metal plate when exposed to irregular heating. Two behavioural parameters like mean temperature value and uniformity on inner surface of plate under variations of thermal properties and geometrical conditions has been studied. The results revealed that conductive metals used as first layer in bi-layer plates have better thermal performance than that of second layer. The usage of all-clad aluminium plate has increased whereas; the all-clad copper and aluminium plate has low temperature gradient than that of single layer aluminium and all-clad aluminium core plates.

Gupta *et al* (2019) conducted study on aluminium utensils which were ubiquitous in developing countries along with India. Common problem by long term usage of aluminium vessels was leaching which causes effects like anaemia, dementia and osteo-malacia, whereas some studies revealed contradictory results that cooking in aluminium utensils and foils was safe. According to them, leaching of metal mostly depends on parameters such as pH, temperature and cooking medium. In healthy controls, 0.01%–1% of orally ingested aluminium was absorbed in gastrointestinal tract which was removed by kidney, whereas sometimes it was stored in tissues and causes improper functioning.

Pramadhony *et al* (2019) revealed analysis of energy efficiency and emission rate of a cookware coated with enamel material. Thermal conductivity of metal cookware was better and used by many people along with some weakness which contaminate food due to its acidic nature. Metal-base material coated with enamel was hard and has non-reactive surface. It has been widely used for processing food but lower thermal conductivity was major problems of enamel cookware. The analysis has been conducted to investigate energy efficiency, emission rate and thermal conductivity of cookware. Energy efficiency was calculated by comparing useful energy (work) with input energy. Emission rate was calculated by multiplying energy consumption with emission factor. Meanwhile the thermal conductivity was calculated by using simply conduction heat transfer equation. Results revealed that much lower thermal conductivity was for enamel cookware than aluminium cookware which does not much affects the efficiency. The most dominant factors which considered were type of fuel and technology of stove which consume higher energy inefficiently and emits much higher hazardous gas.

2.3 Microbial and toxic contents in food cooked indifferent cookware materials

Joel and Halperin (1992) focussed on stainless steel cookware. Stainless steels are widely used material used for cooking. Stainless is easily attacked by means of organic acids, specifically at cooking temperatures; subsequently iron, chromium, and nickel need to be released from the material into the food. Nickel is implicated in several health issues, drastically allergic contact dermatitis. Conversely, chromium and iron are vital nutrients for which stainless could be a useful supply. Domestic cookware was examined by atomic absorption spectroscopy: seven unique stainless cookware in addition to cast iron, moderate metallic, aluminium and enamelled steel. The substances were uncovered to mildly acidic conditions at boiling temperature. Nickel turned into a chief corrosion product from stainless-steel cookware; chromium and iron have been additionally detected. It is recommended that nickel-sensitive patients transfer to a material apart from stainless, and that the stainless-steel cookware enterprise significantly keep in mind switching to a non-nickel formulation.

Penner (2002) reported that Teflon is a tough, nonporous material called per-flourocarbon resin that permits cooking without the use of fats. Non-stick pans do abrade and particles may chip off, but these particles would pass through body and pose no health hazard, when non-stick is overheated, fumes were emitted. And toxicity of fumes give off by the coated pan on dry heating was less than that of fumes given off by ordinary cooking oils such as corn oil, peanut oil and butter.

Jensen *et al* (2003) conducted study on Release of nickel ions from stainless steel alloys used in dental braces and their patch test reactivity in nickel-sensitive individuals. Nickel-containing alloys leached sufficient amounts of Ni which causes sensitivity to allergic people in such cases Nickel-containing stainless steel was used which were safe. This study estimated 3 parameters which were the release of Ni in artificial saliva and sweat from 4 different stainless steel alloys which were commonly used in dental braces. Oral mucosal cells were analyzed for Ni content from three dental patients before and after the attachment of dental braces. Patch test reactivity of the four stainless steel alloys was examined on 31 nickel-sensitive subjects and all four stainless steel alloys released little amounts of nickel ions into artificial saliva (<0_13 mg/cm2/week) and artificial sweat (<0_05 mg/cm2/week); whereas, no measurable amounts of nickel was detected in samples of oral mucosa. None of the 31 nickel-sensitive subjects reacted to patch testing with the four stainless steel alloys showing that these stainless steel alloys would be safe to use in direct and prolonged contact with the skin.

Phyllis and James (2003) reported that aluminium is not heavy metal, but it is toxic in excessive amounts. Even in small amounts, aluminium can be toxic if deposited in the brain. Symptoms were similar to those of Alzheimer's disease and osteoporosis. Aluminium toxicity can lead to colic, rickets, gastrointestinal disturbances, poor calcium metabolism, extreme nervousness, anaemia headache, decreased liver and kidney function, forgetfulness, speech disturbances, memory loss, softening of the bones and weak, aching muscles.

Cimma *et al* (2004) performed a study on effect of consumption of food cooked in aluminium or stainless steel pots on Bangladeshi children with calcium-deficient rickets: an eight month trial. The effects of aluminium or stainless-steel cooking pots on bone metabolism were assessed by measuring blood calcium, phosphorus, alkaline phosphatase, parathyroid hormone, 1,25 dihydroxy vitamin D, aminoterminalpropeptide of type 1 collagen, cross-linked carboxyterminaltelopeptide of type 1 collagen, aluminium and albumin and by analysis of wrist radiographs. In both groups, blood alkaline phosphatase, 1,25dihydroxy vitamin D and aluminium decreased significantly, while serum albumin increased ($p< 0.01$). These results suggest that the nutrition may well be of major importance, whereas the role of aluminium appears to be insignificant.

Bhutani (2005) conducted a study on extent of toxic contents in cooked food: a comparison of different skillets and reported that maximum aluminium content was detected in the *suji halwa* cooked in non-stick skillet (122.29 mg) and maximum chromium contents (0.59 mg) were detected in *suji halwa* prepared in copper skillets. Maximum chromium contents (832 µg) in potato vegetable were detected in vegetable prepared in aluminium skillet, lead content (0.34 mg) in brass skillet and cadmium content in enamelled and tough-coat skillets. Similarly, it was found that maximum chromium (366.5 µg) found in potato chips fried in aluminium skillet and minimum (201 µg) in stainless steel with copper base skillet. Maximum lead content (1.75 µg) found in potato chips fried in brass and minimum in tough-coat skillets. Cadmium was found maximum (70 µg) in stainless steel with copper base and maximum nickel contents were found in chips fried in enamelled skillets and minimum in tough-coat skillet.

Marzec *et al* (2006) conducted study on metal release from cookware. The contact of food with cookware for preparing and storing food poses the risk of metal ions leaching into food. The aim of the study was to determine amounts of chromium, zinc, cadmium, nickel and iron released into soups from pots made of various materials. It was demonstrated that the highest amounts of chromium, nickel and iron were released from stainless steel cookware and of zinc, cadmium and lead from enamelware. Although some elements released may have a significant share in a 24-hour diet, they do not pose any risk to health.

Summer *et al* (2007) conducted a study on patch test reactivity to cobalt-chromium-molebdenum alloy and stainless in metal-allergic patients in relation to metal ion release.Metals like nickel, chromium, and cobalt released from stainless steel and CoCrMo alloys trigged hypersensitivity. 52metal-allergic patients and 48 non-allergic controls were patch tested to stainless steel and CoCrMo discs. The release of nickel, cobalt, and chromium from both materials was assessed upon 2-day exposure to distilled water, artificial sweat (AS), and cell culture medium by using atomic absorption spectrometeTri. Ni ion release from stainless steel (0.3–0.46 mg/cm2/2 days) and CoCrMo discs (up to 0.33 mg/cm2/2 days) was low. Cr release from the 2 materials was also very low (0.06–0.38 mg/cm2/2 days from stainless steel and 0.52–1.36 mg/cm2/2 days from CoCrMo alloy). Apart from Ni being an allergen even cobalt release causes hypersensitivity.

Zubaidy *et al* (2011) conducted study on effect of pH, salinity and temperature on aluminium cookware leaching during cooking. Intake of aluminium is hazardous to humans which causes Alzheimers. This study reveals effects of pH, salinity and temperature of Indian and Egyptian aluminium cookware during cooking using various water types, tap water and drinking water. Alkaline environment increases the corrosion rate of aluminium at low or high pH along with tap water. Increasing concentration of salt resulted in increases the corrosion rate up to a certain value upon which a decrease is observed to reach a plateau of constant corrosion rates. This is attributed to the combination of high conductivity and oxygen solubility.

Layla (2012) predicted aluminium leaching from aluminium cookware in extraordinary vegetable extracts. Four forms of aluminium cookware from one-of-a-kind international locations have been opted from the nearby marketplace: Syria, China, Soudi Arabia and India. The determination of alloying elements was carried out by ICP-MS (Inductively Coupled Plasma the use of Mass Spectrometer). Extracts of 6 greens were organized (onion, tomato, carrot, potato, inexperienced bean and zucchini to make 10-50% (w/v) concentrations. Atomic absorption and Gravimetric approach methods have been used. It was observed that aluminium leaching from aluminium cookware into vegetable extract solutions depends upon aluminium composition, table salt (NaCl), sort of vegetable extracts, water high-quality and temperature immersion time. The predicted aluminium intake in 30 per cent vegetable extract is about 4.56 -5.85 mg/hr for potato extract and the highest value of 7.44-16.44 mg/hr is observed in potato tomato extract. Comparing the prevailing effects with the Provisional Tolerable Weekly consumption of aluminium authorized through the FDA/WHO of one mg/kg body weight in step within a week showed that aluminium leaching from aluminium cookware in a few vegetable extracts may additionally add huge of aluminium doses into the diet. As a consequence tracking of aluminium intake is usually recommended for the aged, youngsters, and those with renal problems.

Kamerud *et al* (2013) reported that stainless steel leaches nickel and chromium into foods during cooking. Toxicological studies found that intake of chromium and nickel can leads to cutaneous adverse reactions like dermatitis. Dietary sources, such as leaching from stainless steel cookware while cooking, are not well characterized. This study tested stainless steel grades, duration of cooking, repetitive cycles of cooking and various types of tomato sauces on nickel and chromium leaching from the cookware. Trials involve 3 varieties of stainless steel and a stainless steel saucepan, duration of cooking for 2-20 hours, ten consecutive cooking cycles and four tomato sauces. After cooking process, samples were analyzed by ICP-MS for Cr and Ni. After six hours of cooking, concentration of Cr and Ni in tomato sauce was increased up to 26-fold and 7-fold respectively, based on the grade of stainless steel. Longer period of cooking resulted increase in metal leaching. Concentration of Ni content was increased 34-fold and Cr content was increased almost 35-fold from the sauces prepared without stainless steel. Cooking with new stainless steel showed drastic increase in metal leaching and decreases with repetitive cooking cycles. Little amounts were detected from the food after the sixth cooking cycle and an average of 86 µg of Cr and 88 µg of Ni leached per 126 g serving of tomato sauce in tenth cooking cycle. Stainless steel cookware can be an unnoticeable source of chromium and nickel where the contribution is dependent on cookware and cooking time.

Odularu *et al* (2013) conducted comparative study of leaching of aluminium from aluminium, clay, stainless steel, and steel cooking pots. The absorption of Al content in boiled rice of 10g was observed when cooked with distilled water in a variety of containers, such as old and new aluminium pots, clay receptacles, stainless steel pots and steel pots. Al levels were known by Colorimetric analysis, new aluminium pots had a concentration of 126 ± 64µg/g, old aluminium pots has 314 ± 128µg/g, new clay pan had 132 ± 68 µ/g, old clay pan had 195 ± 137 µg/g, new steel pots had 241.00 ± 200 µg/g, old steel utensils had 186.83 ± 75.18 µg/g, new stainless steel utensils had 294.83 ± 163 µg/g, and old stainless steel utensils had 289.00 ± 75.155 µg/g. When leaching of Al was observed it was found that old aluminium pots had the highest concentration and was least for new steel pots.

Jaishankar *et al* (2014) studied toxicity, mechanism and health effects of some heavy metals. Heavy metal toxicity was the major threat with various risks of health associated with it. The toxic effects of the metals, do not have any biological role but remain in some or the other harmful form for human body and its proper functioning, which acts as pseudo element and sometimes effects metabolic process. Metals like aluminium can be excreted and few of them get accumulated and becomes chronic. Several measures have been considered to control, prevent and treat metal toxicity occurring at different levels. Metal toxicity depends upon the oral intake, the way of exposure and duration of exposure suck as acute or chronic. This can result in various disorders and leads to excessive damage because of oxidative stress induced by free radical formation.

Said (2015) conducted a study on impact of using the scratched utensil on food contamination with heavy metals. The concentration of heavy metals in food samples were analysed in (Aluminium, Stainless steel, Tefal, Lead, Copper, Glass and Enamel cookware). The samples of cooked were fresh tomato juice cooked in normal and scratched utensil, samples cooled then kept in clean polyethylene bottles with code number, samples digested then analyzed by atomic absorption spectrophotometer (AAS), for six heavy metals (Cd,Ni, Pb, Zn, Cu and Fi). Crush Tefal was found with highest concentrations of mentioned elements. It was recommended to avoid using crushed utensil because it is considered harmful on food and health.

Fralick *et al* (2016) explained lead toxicity by using glazed ceramic cookware. Lead poisoning may be either acute or persistent, despite the fact that the latter is greater not unusual. Manifestation of acute and chronic lead toxicity depends on the severity of lead poisoning. Signs and symptoms are normally non particular and include fatigue, belly pain, constipation, headache, myalgias, arthralgias, hypertension, microcytic anaemia and renal impairment. There is no clearly established concentration of lead in the blood at which no damage occurs. Sub-clinical effects and danger of persistent neurologic, cardiovascular and renal effects may arise at blood lead concentrations as low as 0.48µmol/L. Signs of toxicity usually do no longer occur until blood lead concentrations are more than 2µmol/L. Anaemia typically happens at blood lead concentrations more than 2.5µmol/L, and neurologic signs may manifest when blood lead concentrations greater than 4.5µmol/L. High blood pressure can be discovered with blood lead concentrations extra than 0.48µmol/L, even though this finding is non-specific. Postural stability may be impaired when lead concentrations are inside the variety of 1.5to 3µmol/L, wherein as diffuse abdominal pain can be apparent at concentrations of 2-3µmol/L. Blush pigmentation on the gum-enamel interface, referred to as lead lines, is unusual and no longer a dependable indicator of lead poisoning.

Sajid and Ilyas (2017) studied PTFE (polytetraflouroethylene) coated non-stick cookware and its toxicity worries. PTFE (polytetraflouroethylene)-an inner polymer coating material in non-stick cookware prevents food from sticking inside the pans during cooking procedure. Diverse chemical substances and gases gets released from PTFE- covered cookware at normal cooking temperatures, which ranges from moderate to excessive toxicity.

Simplest studies examine the toxicity levels of PTFE but with no solid conclusions. The fate of ingested PTFE coatings and its toxicity also are no longer understood. However, the rising, chronic, and poisonous environmental pollutant PFOA (perflourooctonoate) is used inside the manufacturing of PTFE. Some reports shows in which PFOA was noticed in the fuel section of the cookware beneath regular cooking temperatures. Because of toxicity worries, PFOA is replaced by other chemical compounds consisting of GenX, but those new substitutes are also known to have similar toxicity. Consequently, more systematic research efforts are required to respond the triumphing dogma regarding human exposure and poisonous consequences to GenX, PFOA, PTFE and different substitutes.

Ogidi *et al* (2017) conducted a follow up study health risk assessment of heavy metal leachabilty from household cookware. Leaching of heavy metals from cook ware causes a major concern of public health. In this study, heavy metals like iron (Fe), aluminium (Al), zinc (Zn), lead (Pb), chromium (Cr) and nickel (Ni) were analyzed using atomic absorption spectrophometery in beans and tomatoes sauce cooked in aluminium and cast-iron cookware's which were commonly used in Nigeria. Small amount of metals was recorded in uncooked food items exceptions were that of Pb, Ni (tomatoes sauce only) and Zn (tomatoes sauce and beans). Higher concentration of Iron (Fe) (1068 mg/kg) was found in tomato sauce cooked in cast iron pot, aluminium (Al) concentration was highest (850 mg/kg) in tomato sauce cooked in aluminium pot. Chromium (Cr) was highest (9.4 mg/kg) in tomato sauce cooked in aluminium pot. Lead (Pb), Zinc (Zn) and Nickel (Ni) was highest (31 mg/kg), (22.6 mg/kg) and (11.9 mg/kg) in uncooked tomato sauce. Food preparation during cooking leaches some amount of trace elements to the food. Concentration level of Lead (Pb), Nickel (Ni) and Zinc (Zn) obtained were within advisable safe limits whereas, concentration level of aluminium (Al), Iron (Fe) and Chromium (Cr) were above their maximum acceptable levels. Cast iron cookware was less harmful compared to aluminium cookware by approximately 1.7-folds through tomatoes sauce and 1.6-folds through beans.

Jain (2018) conducted study on effect of cooking utensil on iron content of food which plays critical part in every living being. Iron deficiency in the body may lead to the most prevalent disease i.e. Anemia which can be controlled by using iron utensil instead of aluminium and stainless steel utensil. X-ray Fluorescence Spectroscopy (XFR) method detects the iron content in food. Iron content in the cooked food was high in those foods which were prepared in iron utensils compared to non-iron utensils which were Increment in 0.007 mg/5 g in bengal gram and 0.0011 mg/5 g increased in beetroot halwa when cooked in iron utensil.

Ntim *et al* (2018) focussed on consumer use effects of nanoparticle release and commercially available ceramic cookware. A ceramic-coated fry pan and ceramic sauce pot (both commercially available) were evaluated for nanoparticle migration under three consumer conditions like washing, scouring, and scratching conditions were simulated by linear abrasion using scrubbing pads, steel wool and tungsten carbide burr attachments. Migration of titanium (Ti) and silicon (Si) was evaluated using 3 per cent acetic acid as food simulant was higher. Titanium dioxide and silicon dioxide nanoparticles were detected in the simulant under the most aggressive use scenario simulated by abrasion with the tungsten carbide burr attachment. Titanium dioxide and silicon dioxide particle number concentrations were on the order of 10^8 and 10^7 particles dm^{-2}, with median diameters of 250 nm and 460nm, respectively.

From the critical appraisal of previous research studies, it may be concluded that there have been some researches conducted to study the functional design, characteristics of metals, thermal efficiency of different heating units. Some work had even been done on the efficiency, heat conductivity and heat retention of cookware also. Although few researches have also been done on saucepans, skillets of different metals long time back yet it was considered important to conduct another study as today's market is flooded with variety of cookware with different finishes due to open market system. Another aspect that cooking food in new cookware materials has any harmful or toxic effect on human body is not been studied so far. So this study is taken in this direction. The findings of this present study will be helpful in providing information to the homemaker for right selection of cookware materials used for surface cooking.

CHAPTER III

MATERIALS AND METHODS

The present study entitled "Thermal Efficiency and Quality of Cooked Food: Evaluation of Cookware Materials" was conducted in three parts and the step by step procedure was adopted for the same and is discussed under following headings:-

3.1 Market survey

3.2 Household survey

3.3 Laboratory experiments

3.1 Market survey

3.1.1 Locale of the study

3.1.2 Selection of sample

3.1.3 Preparation of interview schedule

3.1.4 Pre-testing of interview schedule

3.1.5 Collection of data

3.1.6 Analysis of data

3.1.1 Locale of the study

Mainly five markets of Ludhiana city i.e. *Ghumar Mandi*, *Chaura Bazaar*, Civil Lines, Model Town and *Aggar Nagar* were purposively selected for conducting market survey as these markets were having reasonably good number of crockery stores and were convenient for the researcher to approach.

3.1.2 Selection of sample

From these selected markets a list of all the stores selling different cookware materials was prepared. Then one store from each market was selected randomly thus making the selection of 5 stores for the study.

3.1.3 Preparation of interview schedule

An interview schedule was structured for the collection of data which included general information like name and address of the store, information regarding availability of cookware materials for surface cooking, availability of cookware materials in different capacity and thickness, and frequency of sale in a day etc. (Appendix-I)

3.1.4 Pretesting of interview schedule

The interview schedule was pretested in a non-sampled area and relevant changes and suggestions were incorporated accordingly.

3.1.5 Collection of data

The data were collected through personal interview method using a structured interview schedule. The respondents were explained about the importance of the study and its objectives. After ensuring them of the confidentiality of the information given by them, they agreed to provide reliable information. It was done to minimize the biasness and to get maximum accuracy in data collection from the owners of stores.

3.1.6 Analysis of data

The information collected for the research study was coded, tabulated and analyzed. Frequencies and simple percentages were calculated to get the accurate information from the tabulated data.

3.2 Household survey

3.2.1 Locale of the study

3.2.2 Selection of sample

3.2.3 Preparation of interview schedule

3.2.4 Collection of data

3.2.5 Analysis of data

3.2.1 Locale of the study

The household survey was conducted in different localities of Ludhiana city.

3.2.2 Selection of sample:

For household survey a random sample of 60 households was taken. Working women in Punjab Agricultural University and the households which were located nearby PAU were selected.

3.2.3 Preparation of interview schedule

A comprehensive interview schedule was prepared to collect data from the selected sample. The interview schedule (Appendix-II) comprised of two parts: demographic profile of the respondents and specific information.

3.2.3.1 Demographic profile of the respondents

It constituted the socio-personal characteristics of the respondents and their families like age, education, size of family and occupation of the homemaker.

3.2.3.2 Specific information

It comprised of questions with respect to possession of cookware materials for surface cooking, frequency of use of cookware, type of cookware materials used for different cooking methods and frequency of use of lid while cooking. The responses of the frequency of use of lid was noted on a three point scale i.e. always = 2, sometimes = 1 and never = 0. Mean scores were then calculated with the standard formula.

3.2.4 Collection of data

The data were collected from the homemakers through the personal interview method. Efforts were made to collect the information under conditions considered congenial for obtaining valid and reliable responses. The respondents were explained about the importance of the study and its objectives. After ensuring them of the confidentiality of the information given by them, they were willing to provide reliable information.

3.2.5 Analysis of data

The information collected for the research study was coded, tabulated and analyzed. Frequencies and simple percentages were calculated to get the accurate information from the tabulated data.

3.3 Laboratory experiments

3.3.1 Selection of cookware

3.3.2 Selection of heating unit

3.3.3 Physical characteristics of materials

3.3.4 Selection of recipes

3.3.5 Standardization of the recipes

3.3.6 Selection of panel of judges

3.3.7 Organoleptic evaluation of selected recipes

3.3.8 Fuel consumption

3.3.9 Testing of toxic contents in cooked food

3.3.10 Microbial Estimation of Food Samples

The experiments were conducted in the Equipment laboratory of the department of Family Resource Management, College of Community Science, PAU; Industrial Fermentation Laboratory of the Department of Microbiology, College of Basic Sciences, PAU; Natural Resource Management laboratory, Department of the Soil Science, College of Agriculture, PAU.

3.3.1 Selection of cookware materials

On the basis of the information gathered from the household survey and on the basis of cookware materials available in the market, six commonly used cookware materials with same size were selected for conducting the laboratory experiment. These were stainless-steel pan, non-stick pan, non-stick with ceramic coating pan, non-stick with granite coating pan, hard anodized pan and clay pan. The basic criteria of their selection were the metal and the finish used in the construction.

3.3.2 Selection of heating unit

The most commonly used heating unit in the households i.e. Gas stove was used. A cylinder was used for LPG supply and the cylinder was weighed before and after cooking of each recipe (Kaur, 2015).

3.3.3 Physical characteristics of metal

Heat conductivity and heat retention qualities of the selected cookware were tested as per details given below:

3.3.3.1 Heat conductivity

It was tested by heating 500 ml of coconut oil in each cookware. The rise in temperature from 40^0C was noted down after every minute using a laboratory thermometer for 15 minutes only because after that the coconut oil reached to its smoking temperature. This experiment was conducted twice in each cookware and the average temperature rise was calculated (Bhutani, 2005)

3.3.3.2 Heat retention

Heat retention was tested from the gradual lowering of the temperature per minute from the highest temperature recorded of each cookware. The lowering of the temperature was noted down for 20 minutes with the help of thermometer and a stopwatch. The temperature decline was noted down for only 20 minutes because after that the temperature was lowering down very slowly. This experiment was conducted twice in each cookware and the average temperature decline was calculated (Bhutani, 2005)

3.3.4 Selection of recipes

Two recipes were selected for cooking in different cookware. These were *Jeera* rice (Kaur, 2015) and potatoes with fenugreek leaves vegetable (dry) (Joshi, 2009). These were cooked two times in each cookware (Appendix- IV). The cooking time was fixed for each recipe in all the selected cookware materials.

3.3.5 Standardization of recipes

Recipes were standardized before taking actual readings for fuel consumption, time taken and organoleptic evaluation. These were cooked in different cookware and final recipes were noted down for two preparations. These final recipes were followed during the whole experimentation. Details of the ingredients for each recipe are given in Appendix-IV

3.3.6 Selection of panel of judges

The evaluation of cooked recipes was done to see the extent of their acceptability. A panel of five judges for evaluating the cooked recipes was randomly selected. The panel consisted of the teachers of the Department of Family Resource Management. Every recipe was served twice for evaluation to avoid biasness and errors. The average of two readings was calculated to see the final acceptability.

3.3.7 Organoleptic evaluation of selected recipes cooked in selected cookware materials

The cooked recipes were evaluated for their cooking quality by organoleptic evaluation. This was conducted in terms of appearance, color, taste, texture, flavour, doneness and overall acceptability for cooked *jeera* rice and potatoes with fenugreek leaves vegetable (dry) in selected cookware materials. For every trial each of the two recipes were served to a panel of five judges. The type of cookware in which preparation was made was not disclosed to them. They were asked to rank each recipe out of a total score of 5 for the above-mentioned characteristics. After that these scores were tabulated and mean ranks were calculated with statistical method. To test the significance of difference in mean ranks given by the five judges for two recipes prepared in selected cookware analysis of variance was calculated.

Analysis of variance (ANOVA)

To make the comparison between the selected treatments, the technique of critical difference was calculated for two recipes

$$C.D = \frac{2 \times \Sigma}{N} \times 1.96$$

Where,

$\sum$ = Error mean square

N = No. of respondents

1.96 = Table value of t at 5 per cent level

3.3.8 Fuel consumption

Fuel consumption of each cookware was determined for cooking selected recipes for every trial and then the mean fuel consumption was noted down. Before starting cooking process, the cylinder was weighed for its initial reading and then it was attached to the burner and burner was then ignited for cooking. After cooking was done, again the cylinder was weighed and the final reading was also noted down. In this way the total gas consumption for each recipe was calculated as follows:

Fuel consumption = Initial weight of cylinder (gm) – final weight of cylinder (gm)

3.3.9 Testing of toxic contents in cooked food

3.3.9.1 Drying of the samples (Bhutani, 2005)

Immediately after cooking, 15 gm sample of cooked food was taken in petridish. Second sample was taken after 1 hour from each cookware, till then the cooked food was kept in cookware itself. Each sample was dried in hot air oven for 48 hours at 70^0C. After drying, the sample was again weighed to know the moisture content of cooked food.

Moisture content = Initial weight of the sample (gm) – final weight of the sample (gm)

In the end, dried samples were kept separately is an air tight pouch and were labelled for identification for wet digestion

3.3.9.2 Wet digestion of the samples (Piper, 1950)

Wet digestion of the dried samples was done to make them clear solution for testing the heavy metals which were present in the cooked food.

Reagents

Diacid was the mixture of nitric acid and perflouric acid. Nitric acid and perflouric acid of Analytic Reagents (AR) grade were mixed in the ratio of 5:1 (v/v).

Procedure

Weighed food samples (0.5g) were digested with 10 ml of diacid in conical flask (250 ml). The contents were kept for 5 hours for slow digestion and then heated on hot plate about 1 ml of clear, colourless, liquid was left. The contents were allowed to cool and then transferred with distilled water into a 25 ml volumetric flask after repeated washings and the volume made up to mark. The digested samples were filtered through Whatman No.41 filter paper and kept in decontaminated air tight plastic bottles. For blank 10 ml of diacid mixture was digested as in case of samples and volume made to 25 ml with distilled water. The sample solution is introduced into the ICAP as a fine aerosol of droplets. The aerosol is produce by a nebulizer which aspirates the sample with high velocity to form a fine mist. The aerosol then passes into the torch body, where the aerosol is mixed with more argon gas. ICAP is an excitation source generated by directing the energy of radio frequency generator into a suitable gas. A coupling coil is used to transmit radio frequency to the heated argon gas, producing argon plasma located in the torch. The hot plasma dries any remaining solvent and causes samples atomization. The ICAP detects the atomic emissions produced as light and the process uses ionization. The resulting mass of the ions indicates the elements presents in the sample.

3.3.10 Microbial Estimation of Food Samples

The two recipes which were cooked in all the selected cookware were considered for microbial analysis. The two recipes included *Jeera* rice and Potatoes with fenugreek leaves vegetable (dry) were tested in the laboratory with the help of Bacteriological Food Testing Kit (BFTK).

3.3.10.1 Bacteriological food testing kit

Bacteriological Food Testing Kit (BFTK) is a biphasic kit, the liquid broth provides enrichment medium for the growth of food pathogens and solid medium support the growth of pathogen to detect the visual changes like pellicle, colonies, color change of the slant that serve the purpose of biochemical identification. The kit was devised by adding the defined concentration of components of BFTK and suspending them into 1 litre distilled water. The mixture of the medium was heated to solubilize each component of the kit. 10 ml of the medium was added in each empty serum bottle and closed with the rubber stopper. Thereafter, it was capped with aluminium crimp and the bottles were steam sterilized at 15psi for 10 min (110^0C). For enrichment broth manufacturing, the mixture were dissolved in 1 litre water and steam sterilized at 15 psi for 20 min. Two ml of the broth was then aseptically injected into the bottle with the help of sterilized syringe.

3.3.10.2 Sample collection and identification of microbes

After cooking process, the cooked food was kept in the same cookware for 6 hours and then one gram of food sample was aseptically added in to the kits and incubated for 24-48 hrs at 37^0C. A Specific colour change of slant and butt along with production of gas, pellicle formation and turbidity denotes the presence of indicator and emerging food borne pathogens. Samples were tested for food borne pathogens (*Escherichia coli, Staphylococcus aureus, Salmonella and Shigella spp.*) and emerging pathogens (*Yersinia enterocolitica, Aeromonas hydrophila, Campylobacter jejuni and Bacillus cereus*)

3.3.10.3 Methodology of selective Bacteriological Food Testing Kit

The process for testing samples of cooked food by the Bacteriological Food Testing Kit (BFTK) is done in the following steps:

a) Cut open sealed kit containing the medium.

b) Add aseptically one gram of homogenized food sample in broth and shake it well and close it with rubber stopper.

c) Allow the kit to stand at room temperature and observe the color change and popping off of the rubber stopper within 15 hours.

d) Interpreting the results by comparing with the color chart.

e) Before disposing off the kit, few drops of detol/ disinfectant are added in kit and kept it for 5 minutes.

Operational definitions

Heat conductivity

It is the ability of a given cookware material to conduct/transfer heat during cooking.

Heat retention

Heat retention is the amount of heat a cookware material can store overtime after switching off the gas stove.

Organoleptic evaluation

It is the analysis of food cooked in terms of color, taste, flavour, texture, doneness and overall acceptability.

Moisture content

Moisture content is the quantity of water contained in a food material.

Fuel consumption

The amount of gas consumed for cooking the selected recipe is fuel consumption.

Toxicity

Metal toxicity is the toxic effect of certain metals produced in the food cooked in different cookware materials.

Microbial contamination

It refers to the accidental introduction of infectious pathogens in the cooked food in different cookware materials.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study entitled, "Thermal Efficiency and Quality of Cooked Food: Evaluation of Cookware Materials" have been reported and discussed under the following headings:

4.1 Market survey

4.2 Household survey

4.3 Laboratory experiments

4.1 Market survey

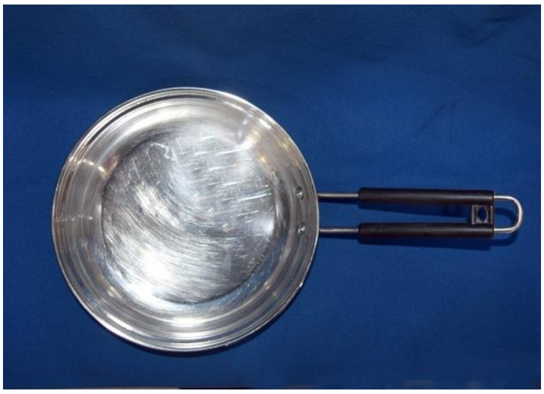
The Market survey was conducted for getting the information from owners of the crockery stores regarding the availability of different cookware materials in different capacity and thickness, availability of cookware materials 'with' or 'without lid', special features of cookware and frequency of sale in a day.

4.1.1 Availability of cookware materials at selected crockery stores in different capacity for surface cooking

Table 4.1 shows the availability of cookware materials in different capacity for surface cooking in selected crockery stores. Availability was checked in four different capacities i.e. between 250-500 ml, 500-1000 ml, 1000-2000 ml and more than 2000 ml. In the capacity of 250-500 ml cookware; the stainless steel cookware was available at all the crockery stores, followed by aluminium with 80.00 per cent of availability across the stores. Whereas, the availability of cast iron cookware, hindalium, hard anodized, non-stick with granite coating and stainless steel with copper base cookware was found to be available at 60.00 per cent crockery stores. The aluminium with marble coating was found to be minimum with 20.00 per cent of availability across the stores.

Further data revealed that in the capacity range of 500-1000 ml, stainless steel and non-stick cookware were found to be available at all the stores (100.00%) followed by aluminium(80.00%). Cookware of cast iron, hard anodized, non-stick with granite coating, non-stick with ceramic coating, hindalium and stainless steel with copper base cookware were found to be available equally with 60.00 per cent availability across the stores. Aluminium with marble coating cookware was found to be available at 20.00 per cent stores.

The perusal of data revealed that in the capacity range of 1000-2000 ml non-stick and stainless steel cookware were widely available across the stores (100.00%) followed by aluminium (80.00%), cast iron, hindalium, hard anodized, non-stick with granite coating, non-stick with ceramic coating and stainless steel with copper base were available at 60.00 per cent stores and cast iron and aluminium with marble coating cookware found minimum availability i.e. 20.00 per cent across the stores.



STAINLESS STEEL PAN

NON-STICK PAN

NON-STICK WITH CERAMIC COATING PAN

NON-STICK WITH GRANITE COATING PAN

HARD ANODIZED PAN

CLAY PAN

From the data presented in the Table 4.1, it was further observed that stainless steel cookware of more than 2000 ml capacity was available at all the selected stores (100.00%) followed by aluminium (80.00%), cast iron, hindalium, hard anodized, non-stick with granite coating, non-stick with ceramic coating and stainless steel with copper base at 60.00 per cent stores. Whereas, availability of cast iron and aluminium with marble coating cookware of more than 2000 ml capacity were not found in any of the selected stores.

Clay pans were not available at any of these selected crockery stores. Availability of clay pans is restricted to only pottery shops in local markets.

Table 4.1 Availability of cookware materials at selected crockery stores in different capacity for surface cooking **n = 5**

Type of cookware materials for surface cooking	Capacity (ml) of cookware			
	250-500	500-1000	1000-2000	More than 2000
Non-stick	2(40.00)	5(100.00)	5(100.00)	1(20.00)
Aluminium	4(80.00)	4(80.00)	4(80.00)	4(80.00)
Stainless steel	5(100.00)	5(100.00)	5(100.00)	5(100.00)
Cast iron	3(60.00)	3(60.00)	1(20.00)	0(00.00)
Hindalium	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Hard anodized	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non stick with ceramic coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel with copper base	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel- Tri ply	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non-stick with granite coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Aluminium with marble coating	1(20.00)	1(20.00)	1(20.00)	0(00.00)
Brass	2(40.00)	2(40.00)	2(40.00)	2(40.00)

Figures in parenthesis indicate percentages

So, we may conclude that stainless steel cookware were available in all the capacities at all selected crockery stores followed by aluminium at 80.00 per cent stores. The non-stick cookware material of more than 2000 ml capacity was available only at one crockery store. Cookware material of non-stick with ceramic coating, hard anodized, stainless steel with copper base, stainless steel-Tri ply and non-stick with granite coating was available in all the capacity at 60.00 per cent crockery stores.

4.1.2 Availability of cookware materials at selected crockery stores'with' and 'without' lid for surface cooking

Table 4.2 depicts the information regarding the availability of cookware materials 'with' and 'without' lid for surface cooking. The results indicate that all the cookware materials were available at all the selected crockery stores both 'with' and 'without' lid, but in case of aluminium, stainless steel, cast iron, non-stick with granite coating at some crockery stores these were available without lid only.

Table 4.2 Availability of cookware materials at selected crockery stores 'with' and 'without' lid for surface cooking **n = 5**

Type of cookware materials for surface cooking	With lid	Without lid
Non-stick	5(100.00)	5(100.00)
Aluminium	2(40.00)	4(80.00)
Stainless steel	4(80.00)	5(100.00)
Cast iron	0(00.00)	3(60.00)
Hindalium	3(60.00)	3(60.00)
Hard anodized	3(60.00)	3(60.00)
Non-stick with ceramic coating	3(60.00)	3(60.00)
Stainless steel with copper base	3(60.00)	3(60.00)
Stainless steel- Tri ply	3(60.00)	3(60.00)
Non-stick with granite coating	2(40.00)	3(60.00)
Aluminium with marble coating	1(20.00)	1(20.00)
Brass	1(20.00)	2(40.00)

Figures in parenthesis indicate percentages

4.1.3 Availability of cookware materials with different thickness (Guage) for surface cooking

Table 4.3 presents the data regarding availability of cookware materials with different thickness for surface cooking at selected crockery stores. The perusal of data revealed that cookware materials for surface cooking were available in different thickness (guage) i.e. Less than 10, 10-12, 12-14, 14-16 and more than 18 guage. At all the selected stores which possessed different cookware materials, each of the cookware material was available in all the different thicknesses. So there was no problem of availability, it depends upon the customer which thickness he/she wants to buy according to their requirement.

Table 4.3 Availability of cookware materials with different thickness (Guage) for surface cooking **n =5**

Type of Cookware materials for surface cooking	Thickness (Guage)				
	Less than 10	10-12	12-14	14-16	more than 18
Non-stick	5(100.00)	5(100.00)	5(100.00)	5(100.00)	5(100.00)
Aluminium	4(80.00)	4(80.00)	4(80.00)	4(80.00)	4(80.00)
Stainless steel	5(100.00)	5(100.00)	5(100.00)	5(100.00)	5(100.00)
Cast iron	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Hindalium	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Hard anodized	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non-stick with ceramic coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel with copper base	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel- Tri ply	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non-stick with granite coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Aluminium with marble coating	1(20.00)	1(20.00)	1(20.00)	1(20.00)	1(20.00)
Brass	2(40.00)	2(40.00)	2(40.00)	2(40.00)	2(40.00)

Figures in parenthesis indicate percentages

4.1.4 Special features of cookware of different materials available for surface cooking

Table 4.4 represents the data regarding special features of cookware of different materials as reported by store owners i.e. easy care, food doesn't burn, proper fixing of handle, proper balance and equal distribution of heat. Pooling of the data from different stores revealed that all the types of cookware materials were easy to care except cast iron cookware (only 20% reported easy care) and stainless steel with copper base as none of the shop owners reported easy care.

Regarding burning of food in different cookware materials, almost all the cookware materials were least prone to food burn except for aluminium, stainless steel and cast iron cookware which are prone to food burn. So these metals are least preferred for surface cooking. Almost all the cookware materials available at selected stores had properly fixed handles except for cast iron cookware. The shop owners further reported that all the available cookware materials irrespective of the metal were properly balanced and good in terms of equal distribution of heat. They were apprehensive about the cast iron cookware as none of the shopkeeper reported that the heat is distributed evenly.

4.1.5 Frequency of sale of different cookware materials for surface cooking

Table 4.5 depicts the information regarding the frequency of sale of different cookware materials per day. Results show that among non-stick and stainless steel cookware, 10 to 20 pieces each were sold per day by the majority of respondents (60.00%).

Table 4.4: Special features of cookware of different materials available for surface cooking n = 5

Type of Cookware materials for surface cooking	Special features of cookware materials				
	Easy care	Food doesn't burn	Proper fixing of handle	Proper balance	Equal distribution of heat
Non-stick	5(100.00)	5(100.00)	5(100.00)	5(100.00)	5(100.00)
Aluminium	4(80.00)	0(00.00)	4(80.00)	4(80.00)	4(80.00)
Stainless steel	5(100.00)	0(00.00)	5(100.00)	5(100.00)	5(100.00)
Cast iron	1(20.00)	0(00.00)	2(40.00)	3(60.00)	0(00.00)
Hindalium	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Hard anodized	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non-stick with ceramic coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel with copper base	0(00.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Stainless steel- Tri ply	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Non-stick with granite coating	3(60.00)	3(60.00)	3(60.00)	3(60.00)	3(60.00)
Aluminium with marble coating	1(20.00)	1(20.00)	1(20.00)	1(20.00)	1(20.00)
Brass	0(00.00)	2(40.00)	2(40.00)	2(40.00)	2(40.00)

Figures in parenthesis indicate percentages

Table 4.5: Frequency of sale of different cookware materials for surface cooking n = 5

Type of Cookware materials for surface cooking	Frequency of sale per day		
	Less than 10 pieces	10 to 20 pieces	More than 20 pieces
Non-stick	2(40.00)	3(60.00)	0(00.00)
Aluminium	4(80.00)	0(00.00)	0(00.00)
Stainless steel	1(20.00)	3(60.00)	1(20.00)
Cast iron	3(60.00)	0(00.00)	0(00.00)
Hindalium	3(60.00)	0(00.00)	0(00.00)
Hard anodized	3(60.00)	0(00.00)	0(00.00)
Non-stick with ceramic coating	3(60.00)	0(00.00)	0(00.00)
Stainless steel with copper base	3(60.00)	0(00.00)	0(00.00)
Stainless steel- Tri ply	2(40.00)	1(20.00)	0(00.00)
Non-stick with granite coating	3(60.00)	0(00.00)	0(00.00)
Aluminium with marble coating	1(20.00)	0(00.00)	0(00.00)
Brass	2(40.00)	0(00.00)	0(00.00)

Figures in parenthesis indicate percentages

As far as stainless steel cookware is concerned 20.00 per cent of stores were also selling more than 20 pieces everyday. The cookware of cast iron, hindalium, non-stick with ceramic coating, hard anodized, non-stick with granite coating, stainless steel with copper base were sold by 60.00 per cent of shop owners (less than 10 pieces per day).Regarding aluminium cookware, less than ten pieces were sold by the 80.00 per cent of selected crockery stores as aluminium is low in cost most of the people with low income prefer aluminium cookware.

It can be concluded from the table 4.5 that stainless steel was most frequently sold cookware followed by non-stick by the selected crockery stores and aluminium with marble coating cookware was least sold as compared to other cookware materials.

4.2 Household survey

The household survey was conducted to get the information regarding the following aspects:

4.2.1 Demographic profile of the respondents

4.2.2 Specific information

4.2.1 Demographic profile of the respondents

The demographic profile of the respondents emphasized on socio-personal traits of the respondents which lead to the systematic understanding and interpretation of results. It included age, education, size of the family and occupation of the respondents`. The information pertaining to the profile of the respondents has been given in Table 4.6.

4.2.1.1 Age

It refers to the chronological age of the respondents. It was categorized into four age groups by using range method (21-30 years, 31-40 years, 41-50 years and 51-60 years). Data in Table 4.6 indicate that age of the respondents varied from 21-60 years. It revealed that 66.67 per cent of the respondents belonged to the age group 41-50 years. Similarly 15.00 per cent of the respondents belonged to age group 31-40 years and only 3.33 per cent belonged to 21-30 years of age group. So it can be said that majority of respondents were in middle age group.

4.2.1.2 Education

As shown in Table 4.6, respondents were categorized into four categories based on their educational qualification. As revealed in table, 60.00 per cent of the respondents were graduate followed by 16.67 per cent post graduate and 15.00 per cent of the respondents who were educated up to 10+2 level. Only 8.33 per cent of the respondents belonged to 'matric' category. This may be due to the reason that the respondents were from the urban area and were well educated.

Table 4.6 Demographic profile of the respondents **n = 60**

Demographic profile	No. of respondents (f)	Percentage (%)
Age (in years)		
21-30	2	3.33
31-40	9	15.00
41-50	37	61.67
51-60	12	20.00
Education		
Matric	5	8.33
10+2	09	15.00
Graduate	36	60.00
Post graduate	10	16.67
Size of Family		
Up to 4 members	44	73.33
5-7 members	12	20.00
8 & above	04	6.67
Occupation of the respondents		
Business	13	21.67
Homemaker	17	28.33
Service	30	50.00

4.2.1.3 Size of Family

Size of family of the respondents was categorized into three i.e. Up to 4 members, 5-7 members, 8 & above. From Table 4.6, it was evident that 73.33 per cent of the respondents had size of the family i.e. Upto 4 members and 20.00 per cent of the respondents belonged to size of family i.e. 5-7 members. Only 6.67 per cent of the respondents belonged to family of size 8 & above. So we may also say that majority of the respondents were belonging to nuclear family type.

4.1.1.4 Occupation of the respondents

Data presented in Table 4.6 further indicates the occupation of the selected respondents. Occupation is further categorized into three categories i.e. service, business, homemaker. Half of the total selected respondents were doing service (50.00%) and 28.33 per cent of the respondents were homemakers. It also revealed that only 21.67 per cent of the respondents belonged to business category. The high education qualification of the respondents may be the reason for their doing the service.

4.2.2 Specific information

This section includes information regarding the possession of cookware materials, frequency of use of cookware materials and type of food cooked in different cookware materials.

4.2.2.1 Possession of cookware materials by the respondents

Table 4.7 depicts the data collected from 60 households regarding the size of cookware possessed by family. Small, medium and large sizes were considered in the survey. In case of small size cookware materials, non-stick and stainless steel were possessed maximum (73.33%) by households; whereas aluminium and hindalium were found to be possessed minimum (6.67%). In case of medium size cookware, non-stick was possessed by all the households (100.00%) followed by stainless steel (93.33%), hard anodized (80.00%), non-stick with ceramic coating and clay pan (73.33%) whereas, aluminium and aluminium with marble coating cookware were found to be least possessed cookware by the households. From the table 4.7 it is clearly evident that, in case of large size cookware, stainless steel cookware was possessed by maximum households (40.00%) followed by non-stick cookware (33.33%) whereas, aluminium was found least (6.67%) among large size cookware across all households.

Table 4.7: Possession of different size of cookware materials by the respondents

n = 60

Type of Cookware materials for surface cooking	Size		
	Small (250-500ml)	Medium (500-1000 ml)	Large (1000-2000 ml)
Non-stick	44(73.33)	60(100.00)	20(33.33)
Aluminium	4(6.67)	8(13.33)	4(6.67)
Stainless steel	44(73.33)	56(93.33)	24(40.00)
Cast iron	8(13.33)	20(33.33)	8(13.33)
Hindalium	4(6.67)	24(40.00)	12(20.00)
Hard anodized	24(40.00)	48(80.00)	12(20.00)
Non stick-ceramic coating	24(40.00)	44(73.33)	20(33.33)
Stainless steel with copper base	16(26.67)	20(33.33)	12(20.00)
Stainless steel- Tri ply	16(26.67)	24(40.00)	8(13.33)
Non-stick granite coating	16(26.67)	44(73.33)	16(26.67)
Aluminium with marble coating	0(00.00)	8(13.33)	0(00.00)
Brass	8(13.33)	16(26.67)	8(13.33)
Clay pan	16(26.67)	44(73.33)	12(20.00)

Figures in parenthesis indicate percentages
*Multiple response

So, it can be concluded that non-stick cookware was possessed by maximum number of respondents followed by stainless steel, non-stick with ceramic coating, hard anodized, clay cookware and non-stick with granite coating cookware. Aluminium and aluminium with marble coating were least possessed by the respondents.

4.2.2 Frequency of use of different cookware materials by the respondents

The data collected from households regarding frequency of use of different cookware materials has been presented in table 4.8. The frequency of use of cookware materials by respondents was noted thrice a day, twice a day, once a day, on alternate basis, weekly and rarely used. The results reveal that the most frequently used cookware for surface cooking was stainless steel as 33.33 per cent respondents use it thrice a day, 53.33 percent use it twice a day and 13.33 percent used stainless steel once a day. The second most frequently used is non-stick cookware as 66.67 per cent respondents use it twice a day and 33.33 per cent use it once a day.

Table 4.8: Frequency of use of different cookware materials by the respondents

n = 60

Type of Cookware materials for surface cooking	Thrice a day	Twice a day	Once a day	Alternate day	Weekly	Rarely
Non-stick	0(00.00)	40(66.67)	20(33.33)	0(00.00)	0(00.00)	0(00.00)
Aluminium	0(00.00)	0(00.00)	0(00.00)	4(6.67)	12(20.00)	0(00.00)
Stainless steel	20(33.33)	32(53.33)	8(13.33)	0(00.00)	0(00.00)	0(00.00)
Cast iron	0(00.00)	4(6.67)	12(20.00)	12(20.00)	8(13.33)	0(00.00)
Hindalium	0(00.00)	4(6.67)	8(13.33)	8(13.33)	0(00.00)	0(00.00)
Hard anodized	0(00.00)	12(20.00)	28(46.67)	8(13.33)	0(00.00)	0(00.00)
Non stick with ceramic coating	0(00.00)	4(6.67)	32(53.33)	12(20.00)	0(00.00)	0(00.00)
Stainless steel with copper base	4(6.67)	12(20.00)	8(13.33)	0(00.00)	0(00.00)	0(00.00)
Stainless steel-Tri ply	0(00.00)	8(13.33)	28(46.67)	12(20.00)	0(00.00)	0(00.00)
Non-stick with granite coating	0(00.00)	0(00.00)	40(66.67)	4(6.67)	0(00.00)	0(00.00)
Aluminium with marble coating	0(00.00)	0(00.00)	0(00.00)	8(13.33)	0(00.00)	0(00.00)
Brass	0(00.00)	0(00.00)	0(00.00)	0(00.00)	8(13.33)	8(13.33)
Clay pan	0(00.00)	0(00.00)	16(26.67)	4(6.67)	20(33.33)	4(6.67)

Figures in parenthesis indicate percentages
*Multiple response

The non-stick with ceramic coating cookware hard anodized, stainless steel with copper base and non-stick with granite coating are mostly used twice a day or once a day by majority of the respondents. The aluminium and brass cookware were very less frequently used. Clay pan is also used but only 26 per cent use it daily rest of them use it mostly weekly.

So non-stick cookware and stainless steel cookware are the most frequently used cookware materials among the respondents for surface cooking. Hard anodized, non-stick with ceramic coating cookware was used almost once a day.

4.2.3 Type of cookware materials used for different cooking methods by the respondents

The data related to type of cookware materials used for different cooking methods has been presented in the Table 4.9. The data depicted that the non-stick cookware was used maximum for cooking dry vegetables (66.67%) and the minimum used for deep frying (13.33%). Aluminium cookware was used maximum for heating vegetables (26.67%) and minimum for curry vegetables (6.67%). The data from the table showed that stainless steel cookware was used maximum for boiling vegetables (93.33%) and minimum used for cooking dry vegetables (6.67%). Maximum households were using cast iron cookware for shallow frying (46.67%) whereas, minimum for preparing *tarka* (6.67%). Hindalium cookware was used maximum for boiling vegetables (33.33%) and minimum for deep frying (6.67%). Maximum respondents used hard anodized for cooking curry vegetable (60.00%) and minimum for boiling vegetables (13.33%). Non-stick with ceramic coating cookware was used maximum for cooking curry vegetable (80.00%) and minimum used for shallow frying (13.33%). Maximum respondents used stainless steel with copper based used for boiling vegetables (40.00%) and minimum (6.67%) used for heating vegetable. Further, the data revealed that stainless steel with Tri ply cookware was used for cooking dry vegetables (26.67%) and minimum for boiling vegetables and deep frying (6.67%). Non-stick with granite coating was used maximum for cooking curry vegetable (60.00%) and minimum for deep frying (6.67%).Whereas, aluminium with marble coating used maximum for preparing *tarka* (13.33%). Brass cookware was used maximum for roasting (26.67%) and minimum for cooking vegetables (13.33%). The perusal of the data revealed that clay pan was maximum used for cooking curry vegetables (80.00%) and minimum for heating vegetables (6.67%).

It can be inferred from the data of Table 4.9 that for boiling vegetables maximum respondents used stainless steel cookware and for cooking dry vegetables non-stick, non-stick with granite coating, hard anodized and non-stick with ceramic coating were used. Similarly, hard anodized and stainless steel with copper base cookware was used for deep frying. Non-stick with ceramic coating was used for preparing *tarka*, heating vegetables and cooking curry vegetables. For roasting purpose people preferred non-stick cookware.

Table 4.9 Type of cookware materials used for different cooking methods by the respondents **n = 60**

Type of cookware materials for surface cooking	Boiling vegetables	Cooking dry vegetables	Deep frying	Preparing *tarka*	Heating vegetables	Cooking curry vegetables	Shallow frying	Roasting
Non-stick	12(20.00)	40(66.67)	8(13.33)	32(53.33)	24(40.00)	36(00.00)	12(20.00)	24(40.00)
Aluminium	4(6.67)	0(00.00)	0(00.00)	0(00.00)	16(26.67)	4(6.67)	0(00.00)	12(20.00)
Stainless steel	56(93.33)	4(6.67)	0(00.00)	0(00.00)	4(6.67)	0(00.00)	0(00.00)	16(26.67)
Cast iron	0(00.00)	0(00.00)	0(00.00)	4(6.67)	12(20.00)	0(00.00)	28(46.67)	16(26.67)
Hindalium	20(33.33)	8(13.33)	4(6.67)	0(00.00)	4(6.67)	0(00.00)	4(6.67)	16(26.67)
Hard anodized	8(13.33)	28(46.67)	16(26.67)	32(53.33)	28(46.67)	36(60.00)	12(20.00)	12(20.00)
Non-stick with ceramic coating	0(00.00)	24(40.00)	0(00.00)	40(66.67)	32(53.33)	48(80.00)	8(13.33)	8(13.33)
Stainless steel with copper base	24(40.00)	12(20.00)	20(33.33)	16(26.67)	4(6.67)	8(13.33)	4(6.67)	8(13.33)
Stainless steel- Tri ply	4(6.67)	16(26.67)	4(6.67)	12(20.00)	12(20.00)	16(26.67)	8(13.33)	12(20.00)
Non-stick with granite coating	0(00.00)	32(53.33)	4(6.67)	44(73.33)	20(33.33)	36(60.00)	20(33.33)	8(13.33)
Aluminium with marble coating	0(00.00)	4(6.67)	4(6.67)	8(13.33)	4(6.67)	4(6.67)	4(6.67)	4(6.67)
Brass	0(00.00)	8(13.33)	12(20.00)	0(00.00)	8(13.33)	8(13.33)	8(13.33)	16(26.67)
Clay pan	24(40.00)	20(33.33)	0(00.00)	24(40.00)	4(6.67)	48(80.00)	0(00.00)	24(40.00)

Figures in parenthesis indicate percentages
*Multiple response

4.2.4 Frequency of use of lid of cookware materials by the respondents:

The responses on frequency of use of lid on cookware while cooking by the respondents were recorded are presented in Table 4.10. The data from the table depicted that the respondents mostly used lid while cooking in cookware materials like clay pan, non-stick with granite coating, stainless steel- Tri ply and non-stick with ceramic coating (mean score 1.26 and 1.06 respectively). While cooking in cookware materials like hindalium, stainless steel, aluminium with marble coating and cast iron mostly lid was not used (mean score less than 0.5)

Table 4.10 Mean scores for frequency of use of lid of cookware materials by the respondents **n = 60**

Types of Cookware materials for surface cooking	Frequency of use of lid			
	Always	Sometimes	Never	Mean score
Non-stick	0(00.00)	56(93.33)	4(6.67)	0.92
Aluminium	0(00.00)	16(26.67)	0(00.00)	0.26
Stainless steel	0(00.00)	28(46.67)	28(46.67)	0.46
Cast iron	0(00.00)	4(6.67)	24(40.00)	0.07
Hindalium	0(00.00)	24(40.00)	0(00.00)	0.40
Hard anodized	0(00.00)	48(80.00)	0(00.00)	0.80
Non-stick with ceramic coating	16(26.67)	32(53.33)	0(00.00)	1.06
Stainless steel with copper base	16(26.67)	20(33.33)	12(20.00)	0.86
Stainless steel- Tri ply	16(26.67)	44(73.33)	8(13.33)	1.26
Non-stick with granite coating	16(26.67)	44(73.33)	16(26.67)	1.26
Aluminium with marble coating	0(00.00)	8(13.33)	0(00.00)	0.14
Brass	8(13.33)	16(26.67)	8(13.33)	0.54
Clay pan	16(26.67)	44(73.33)	12(20.00)	1.26

Figures in parenthesis indicate percentages

4.3 Laboratory experiments

Based on the results of the survey six commonly used cookware materials were selected for conducting laboratory experiments. It was found that the respondents were mostly using pans for cooking small quantities of vegetables. So, these were stainless steel pan, non-stick pan, non-stick with ceramic coating pan, non-stick with granite coating pan, hard anodized pan and clay pan.

All the selected cookware materials were of same capacity and similar size. The results pertaining to the experiments are presented below:

4.3.1Heat Conductivity

Table 4.11 and Fig. 1 depicts the data of heat conductivity of different cookware materials. From the table and figure, it is clearly evident that hard anodized pan was found to be best in terms of heat conductivity among all the selected cookware materials as it can be seen from rise in maximum temperature up to 182^0C. Then non-stick with ceramic coating pan was also found good as it reached maximum heat up to 180^0C followed by non-stick with granite coating pan with 179^0C temperature. The results have shown that the rise in temperature of clay pan was 175^0C as clay cannot withstand high heat. It can be breakable at high temperatures. However, it can be concluded that stainless steel was poor conductor of heat as there was slow rise in temperature maximum up to 170^0C.

Table 4.11 Heat conductivity of selected cookware materials for surface cooking for 15 min. (Temp. in ^{0}C)

Time in minutes	Stainless steel pan	Hard anodized pan	Non-stick pan	Non-stick with ceramic coating pan	Non-stick with granite coating pan	Clay pan
1	46.50	44.00	48.00	47.50	52.50	47.00
2	52.50	52.50	60.50	56.50	60.00	54.00
3	61.00	71.00	72.50	66.50	68.00	62.00
4	69.00	80.00	81.50	80.50	79.50	75.00
5	80.50	93.50	89.00	92.00	91.00	83.00
6	92.00	102.75	98.00	102.50	108.50	91.00
7	104.50	117.50	109.00	112.00	119.50	102.00
8	119.00	124.50	118.00	119.00	127.00	116.00
9	125.50	138.00	126.00	130.00	137.00	128.00
10	130.50	147.50	136.00	138.00	144.00	133.00
11	136.50	155.00	147.50	149.00	152.00	140.00
12	148.00	162.50	156.00	158.50	157.50	149.00
13	154.00	169.50	164.00	165.00	166.50	156.00
14	163.50	174.00	172.50	171.00	171.00	164.00
15	170.00	182.00	178.00	180.00	179.00	175.00

Reading Start after 40^0C up to 15 minutes (per min.)

4.3.2 Heat retention

The perusal of the data in table 4.12 and Fig. 2 showed that among all the selected cookware materials, stainless steel retained maximum heat after 20 minutes of cooking with 119^0C. Non-stick with ceramic coating pan and hard anodized pan also retained good amount of heat with 112^0C, 109^0C respectively; whereas, clay pan was proven to be least at retention of heat with temperature 101^0C. It was observed that non-stick pan did not retain good amount of head. Similar results were reported by Bhutani (2005). It was found that non-stick had least retention of heat compared to other cookware materials like tough coat, hindalium, aluminium, iron, brass with tin plating and stainless steel with copper base.

Table 4.12 Heat retention of selected cookware materials for surface cooking for 20 min. (Temp. in ^{0}C)

Time in minutes	Stainless steel pan	Hard anodized pan	Non-stick pan	Non-stick with ceramic coating pan	Non-stick with granite coating pan	Clay pan
20	170.00	182.00	178.00	180.00	179.00	175.00
19	168.00	179.00	173.30	178.00	176.00	172.00
18	166.00	174.00	169.50	175.00	173.50	168.00
17	163.00	168.00	167.00	171.00	170.00	164.00
16	161.00	164.00	164.00	168.00	166.00	160.00
15	158.00	159.00	160.75	165.00	160.00	155.00
14	156.00	156.00	157.50	162.50	156.00	151.00
13	153.00	153.00	155.00	157.00	151.00	148.00
12	149.00	149.00	152.00	153.00	147.00	143.00
11	147.00	145.00	150.00	148.00	144.00	139.00
10	145.00	143.00	148.00	145.00	138.00	136.00
9	143.00	139.00	145.75	142.50	135.00	131.00
8	139.00	135.00	140.00	138.50	133.00	127.00
7	135.00	132.00	136.00	132.00	129.00	122.00
6	131.00	128.00	132.00	128.00	125.00	118.00
5	129.00	125.00	128.00	125.00	120.00	115.00
4	126.00	121.00	124.00	122.00	116.00	111.00
3	124.00	116.00	117.00	118.50	112.00	108.00
2	121.00	113.00	111.00	114.50	110.00	105.00
1	119.00	109.00	108.00	112.00	107.00	101.00

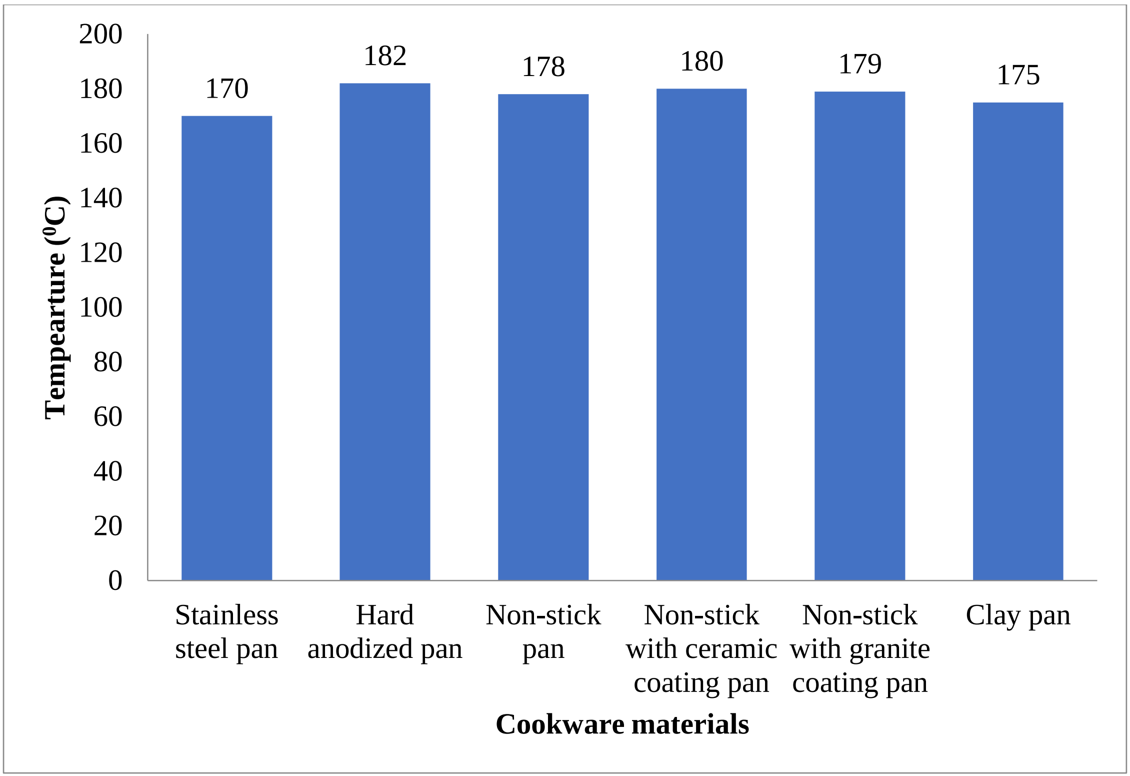


Fig. 1: Graphical representation of heat conductivity of selected cookware materials for 15 minutes

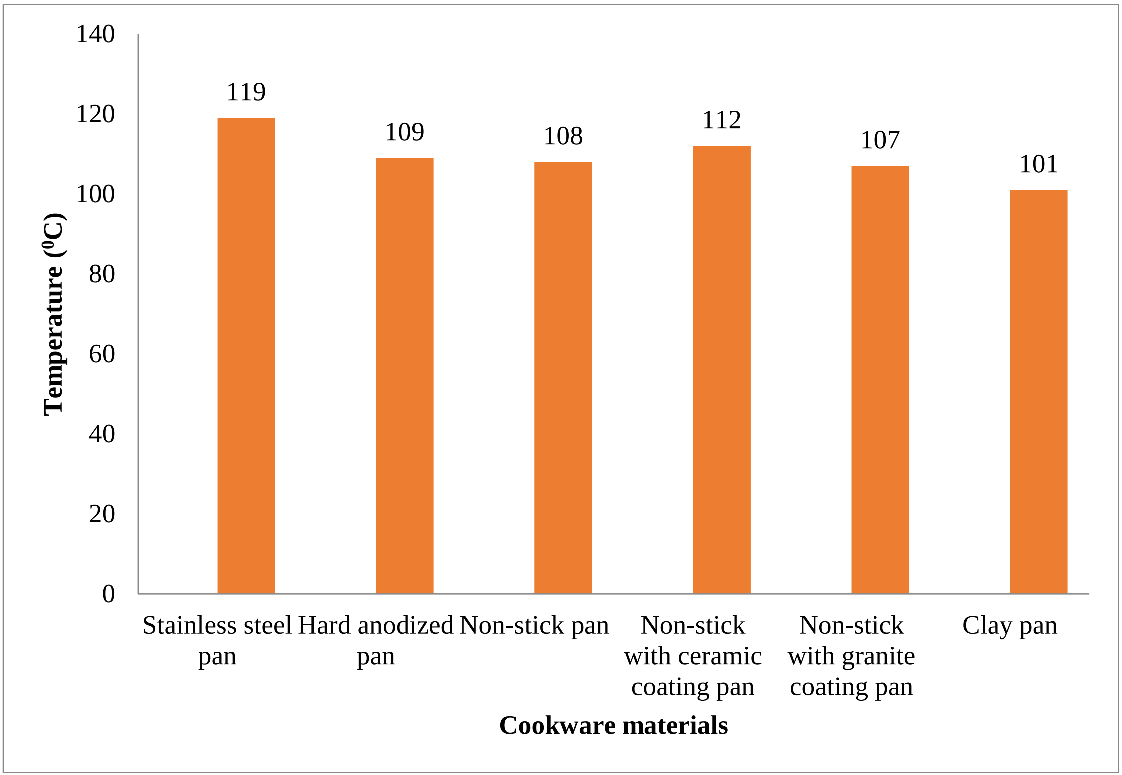


Fig. 2: Graphical representation of heat retention of selected cookware materials for 20 minutes

4.3.3 Fuel consumption of different materials for selected recipes

Data incorporated in Table 4.13 indicate the fuel consumption of different cookware materials for selected recipes i.e. *jeera* rice and potatoes with fenugreek leaves vegetable (dry). From the below table and Fig. 3, it is clearly evident that minimum fuel consumption for *jeera* rice is observed in stainless steel pan (29.00 gm) followed by hard anodized pan and non-stick with ceramic coating pan i.e. (29.75 gm) and (30.00 gm) respectively. Whereas the maximum amount of fuel consumption was observed in non-stick pan (31.20 gm). 30.50 gm fuel was consumed for both of the non-stick with granite coating pan and clay pan for cooking *jeera* rice.

Table 4.13 Fuel consumption (in grams) of different cookware materials for selected recipes

S. No.	Cookware materials	Fuel consumption (gm)	
		***Jeera* rice**	**Potatoes with fenugreek leaves vegetable (dry)**
1	Stainless steel pan	29.00	33.80
2	Non-stick pan	31.20	35.00
3	Nonstick with ceramic coating pan	30.00	34.00
4	Nonstick with granite coating pan	30.50	34.20
5	Hard anodized pan	29.75	33.90
6	Clay pan	30.50	34.50

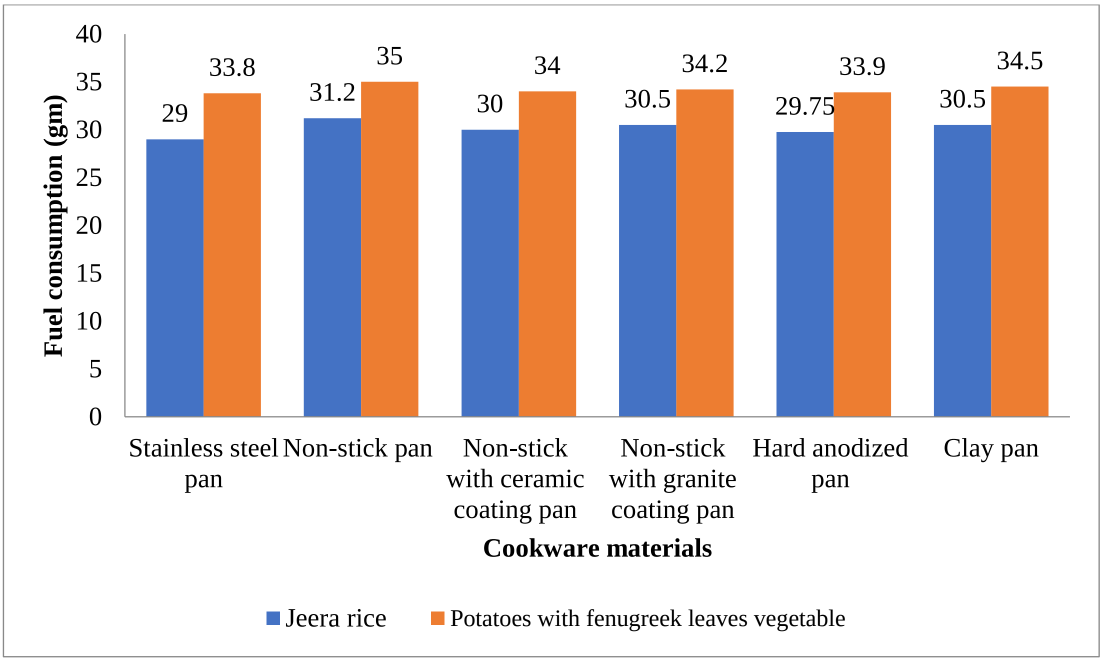


Fig. 3: Fuel consumption of selected cookware materials for cooking *jeera* rice and potatoes with fenugreek leaves vegetable (dry)

Similarly, in case of potatoes with fenugreek leaves vegetable (dry), the minimum fuel consumption was seen in stainless steel pan (33.80 gm) followed by hard anodized pan (33.90 gm) and non-stick with ceramic coating pan (34.00 gm) respectively. Maximum of fuel consumed for non-stick pan i.e. 35.00 gm. For non-stick with granite coating pan, the consumption of fuel was 34.20 gm.

Batish and kiran (1980) concluded that the minimum consumption of fuel was due to their larger diameter. Similarly, from our results it was found that stainless steel pan, hard anodized pan, non-stick with ceramic coating pan and non-stick with granite coating had larger diameter, heat was evenly distributed so they consumed less fuel whereas clay pan and non-stick pan consumed more fuel for cooking *jeera* rice and potatoes with fenugreek leaves vegetable (dry) because of the smaller diameter of the pans though the capacity of the pans were same for all selected cookware.

4.3.4 Organoleptic evaluation of standardized recipes prepared in selected cookware materials

In organoleptic evaluation, the palatability of cooked recipes was tested. The two standardized recipes were made twice in all the selected cookware materials. After cooking recipes were served to the panel of five judges. The recipes were judged for their appearance, texture, taste and flavour, doneness and overall acceptability. In Table 4.14 and 4.15 the mean scores from two trials of each recipe are presented.

From the data it was revealed that non-stick with ceramic coating pan was best for *jeera* rice as it was ranked first followed by non-stick and non-stick with granite coating pan.

It was evident that stainless steel pan was not good for cooking *jeera* rice as it was ranked least among all the selected pans followed by hard anodized pan in comparison to other cookware materials. Similarly, in case of potatoes with fenugreek leaves vegetable (dry) it was evident from the table 4.15 that non-stick with ceramic coating pan was ranked first as it came out best in comparison with other pan followed by non-stick pan and non-stick with granite coating pan. Stainless steel pan was ranked least for potatoes with fenugreek leaves vegetable (dry) followed by hard anodized as these were observed to be poor taste & flavour, texture, not well cooked. This may be because of the reason that the food cooked in stainless steel pan burns easily thus spoiling the taste and flavour of the food.

Table 4.14 Mean ranks for organoleptic evaluation of "*Jeera* rice" prepared in selected cookware materials

Type of cookware materials	Appearance	Texture	Taste & flavor	Doneness	Overall acceptability	Total score	Mean score	Mean rank
Non-stick with ceramic coating pan	3.83	4.10	3.80	3.80	3.80	19.33	3.86	1
Non-stick pan	3.63	3.76	3.53	3.60	3.60	18.13	3.62	2
Non-stick with granite coating pan	3.60	3.46	3.60	3.33**	3.53	17.53	3.50	3
Clay pan	3.33	3.23**	3.06**	3.00**	3.40	16.03	3.20	4
Hard anodized pan	2.96**	3.03**	3.20**	2.80**	3.00**	15.00	3.00	5
Stainless steel pan	2.60**	2.73**	2.70**	2.60**	2.53**	13.16	2.63	6
F- value	3.66	3.87	7.23	13.46	11.23			
Critical differences	**0.75**	**0.78**	**0.46**	**0.39**	**0.43**			

** Significant at 5 % level
Range of scores (1-5)
Scores for various parameters

5- Excellent **4- Very good** **3- Good** **2- Fair** **1- Poor**

Table 4.15 Mean ranks for organoleptic evaluation of "Potatoes with fenugreek leaves vegetable (dry)" prepared in selected cookware materials

Type of cookware materials	Appearance	Texture	Taste & flavor	Doneness	Overall acceptability	Total score	Mean score	Mean rank
Non-stick with ceramic coating pan	3.80	3.60	3.40	3.73	3.60	18.13	3.62	1
Non-stick pan	3.60	3.50	3.20	3.70	3.70	17.70	3.54	2
Non-stick with granite coating pan	3.33**	3.80	3.20	3.60	3.40	17.33	3.46	3
Clay pan	2.90**	3.00**	2.80**	2.93**	2.80**	14.43	2.89	4
Hard anodized pan	3.20**	2.60**	2.80**	2.90**	2.70**	14.20	2.84	5
Stainless steel pan	3.26**	2.80**	2.63**	2.40**	2.60**	13.70	2.74	6
F- value	4.51	20.02	7.32	26.03	23.86			
Critical differences	**0.46**	**0.33**	**0.34**	**0.33**	**0.31**			

**Significant at 5% level
Range of scores (1-5)
Scores for various parameters

5- Excellent **4- Very good** **3- Good** **2- Fair** **1- Poor**

4.3.5 Average moisture content of selected recipes in different cookware materials

Moisture content of food is important to consider whether the food is suitable before consumption because it affects the physical appearance, freshness, shelf-life, quality and resistance to bacterial contamination. If the moisture content is high, then there may be more chances of spoilage of food and also microbial contamination. To compare the average moisture content in different cookware materials, *jeera* rice and potatoes with fenugreek leaves vegetable (dry) were prepared in all selected cookware using standardized recipe. The results are presented in this table.

Table 4.16 Average moisture content (in grams) of selected recipes in different cookware materials

S. No.	Type of cookware materials	*Jeera* rice	Potatoes with fenugreek leaves vegetable (dry)
1.	Stainless steel pan	7.43	9.11
2.	Non-stick pan	7.30	7.98
3.	Non-stick with ceramic coating pan	7.25	7.86
4.	Non-stick with granite coating pan	7.33	8.85
5.	Hard anodized pan	7.32	8.42
6.	Clay pan	7.35	8.50

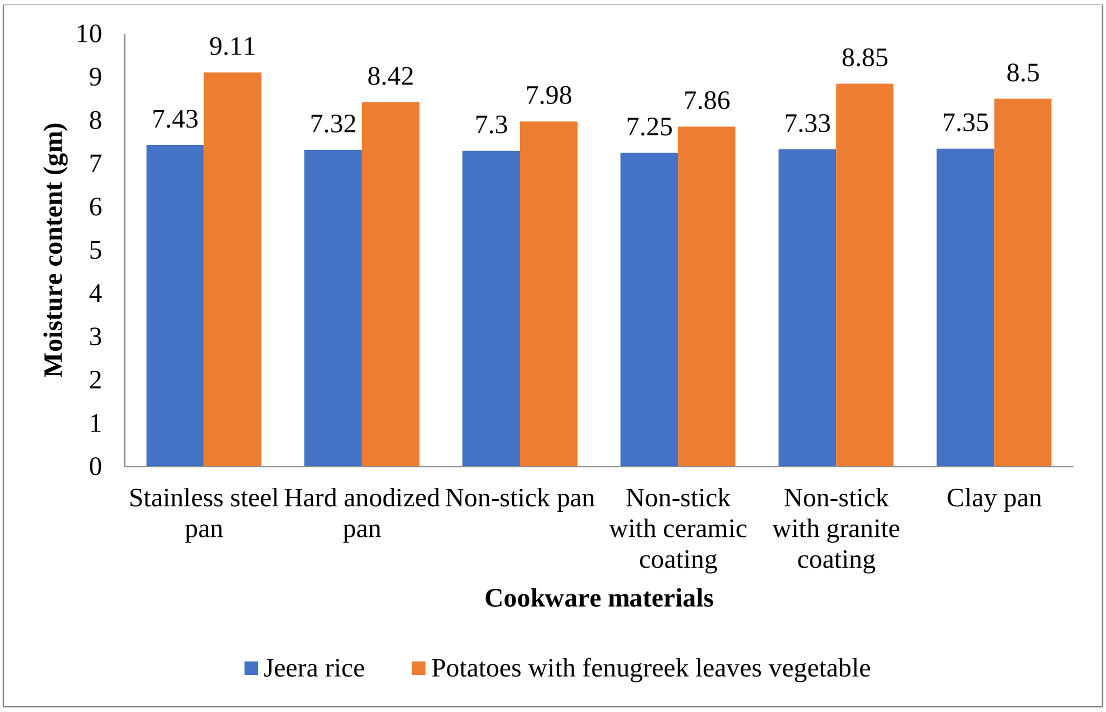


Fig. 4: Per cent moisture content of jeera rice and potatoes with fenugreek vegetable (dry) in selected cookware materials

The data incorporated in Table 4.16 and Fig. 4 compares the average moisture content of selected recipes in different cookware materials. The results reveal that in *jeera* rice, minimum moisture content was found in non-stick with ceramic coating pan (7.25 gm) followed by non-stick pan (7.30gm) and hard anodized pan (7.32gm). Maximum moisture content was found in stainless steel pan (7.43 gm). Similar were the results found in other recipe i.e. potatoes with fenugreek leaves vegetable (dry). Minimum moisture content was found in non-stick with ceramic coating pan (7.86 gm) followed by non-stick pan (7.98 gm) and hard anodized pan (8.42 gm). Maximum moisture content was found in stainless steel pan (9.11 gm).

Moisture content of the food is important to consider whether the food is suitable for the consumption or not, because it affects the physical and chemical aspects of food which relates with the freshness and stability for the storage of the food for longer period of time. The moisture rich foods will result in microbial attack at a faster rate.

4.3.6 Heavy metal toxicity of *jeera* rice prepared in selected cookware materials

Table 4.17 illustrated the trace elements in cooked rice in different cookware materials. In the raw sample, chromium (Cr) content was about 0.15 mg, nickel (Ni) was 0.10 mg and arsenic (As) was 0.01 mg. There is no significant amount of cadmium and lead (Said, 2015). This might be due to the utilization of chemical fertilizers for rice production. Cooking in different cookware increased the amounts of heavy metals such as Cr, Ni, As, Cd and Pb. It is clear from the table that the chromium content was found to be maximum in the rice sample which was cooked in non-stick pan (0.36 mg) followed by stainless steel pan (0.35 mg) and hard anodized pan (0.32 mg). Minimum amount of chromium was found in non-stick with granite coating pan (0.22 mg). Whereas, after 1 hour of cooking higher content of chromium was found in stainless steel pan (0.72 mg) followed by non-stick pan (0.66 mg) followed by hard anodized pan (0.64 mg) and minimum found in non-stick with ceramic coating pan (0.45 mg). But it can be further seen that in all samples chromium contents were found to be more than the permissible limits i.e. 0.20 mg/day. In stainless steel pan, the samples which were collected after 1 hour of cooking, the chromium content was doubled (refer fig. 5). Similar results were reported by Odularu *et al* (2013) and Kamerud *et al* (2013).They observed that after 6 hours of cooking, the heavy metal contamination was increased more than 26 times. This clearly shows that with the cooking and storage time, the contamination is also increasing.

It can be seen that maximum content of nickel was found in rice sample that was cooked in stainless steel (0.44 mg) followed by hard anodized (0.38 mg) and non-stick pan (0.35 mg) whereas, minimum amount of nickel was found in *jeera* rice that was cooked in clay pan and non-stick with ceramic coating pan (0.20 mg and 0.22 mg) respectively. Further analysis of the data showed that after one hour of cooking maximum content of nickel was found in stainless steel (0.52 mg) followed by hard anodized (0.41 mg) and non-stick pan (0.38 mg) whereas, minimum amount of nickel was found in rice that was cooked in clay pan i.e.0.22 mg (refer fig. 6). The toxicology studies on dosages of chromium, nickel which causes many effects such as dermatitis (Said 2015).

The perusal of data showed that maximum arsenic contents were found in the rice sample that was cooked in the stainless steel pan (0.8 mg) and hard anodized (0.8 mg) followed by non-stick with granite coating pan (0.7 mg) and non-stick with ceramic coating pan (0.7 mg), whereas minimum content was found in non-stick pan (0.6 mg) and clay cookware (0.6 mg). Further, it was observed from the data after that one hour of cooking maximum arsenic content was found in hard anodized cookware (0.11 mg) followed by stainless steel (0.10 mg) and minimum amount was found in non-stick cookware i.e. 0.07 mg (refer Fig. 7).

Data in the table depicted that maximum cadmium contents were found in the *jeera* rice that was cooked in stainless steel (0.02 mg) and followed by non-stick, non-stick with ceramic coating pan, hard anodized pan, non-stick with granite coating pan and clay pan with minimum content of (0.01 mg). After one hour of cooking, higher content of cadmium recorded in stainless steel pan with 0.03 mg and the minimum was being recorded in clay pan with 0.01 mg. However, the cadmium content that was recorded across all cookware was satisfactory and within the permissible limits (0.03 mg/day).

The perusal of the data revealed that highest lead content in *jeera* rice was found in stainless steel pan (0.37 mg)followed by hard anodized pan (0.32 mg) and minimum was recorded in clay pans (0.06 mg) and non-stick with ceramic coating (0.09 mg). Further data depicted that one hour after cooking maximum lead content was found in the hard anodized pan (0.87 mg) followed by stainless steel pan (0.48 mg); whereas minimum content was found in samples that were collected in clay pans (0.15 mg) and non-stick with ceramic coating (0.18 mg). Both stainless steel and hard anodized pans released higher levels of lead into the cooked food than permissible limits (0.30 mg/day). Implications on health include fatigue, belly pain, constipation, headache, myalgias, arthralgias, hypertension, microcytic anaemia and renal impairment (Fralick *et al* 2021).

Similar study was conducted by Zhou *et al* (2017). They concluded that, with the process of cooking, heavy metal contamination in food was increased. The time and temperature play an important role in leaching of heavy metals from the cookware materials to food materials.

Table 4.17 Heavy metal toxicity in *Jeera* rice prepared in different cookware materials

Type of cookware materials	Chromium (mg)		Nickel (mg)		Arsenic (mg)		Cadmium (mg)		Lead (mg)	
	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking
Raw sample	0.15	-	0.10	-	0.01	-	-	-	-	-
Stainless steel pan	0.35	0.72	0.44	0.52	0.08	0.10	0.02	0.03	0.37	0.48
Non-stick pan	0.36	0.66	0.35	0.38	0.06	0.07	0.01	0.02	0.15	0.25
Non-stick with ceramic coating pan	0.28	0.45	0.22	0.23	0.07	0.08	0.01	0.02	0.09	0.18
Non-stick with granite pan	0.22	0.49	0.25	0.26	0.07	0.09	0.01	0.02	0.10	0.21
Hard anodized pan	0.32	0.64	0.38	0.41	0.08	0.11	0.01	0.02	0.32	0.87
Clay pan	0.30	0.58	0.20	0.22	0.06	0.08	0.01	0.01	0.06	0.15
Permissible Limits	0.05-0.20 mg/day		Safe but allergic		0.12 mg/ day		0.03 mg/day		0.3 mg/day	

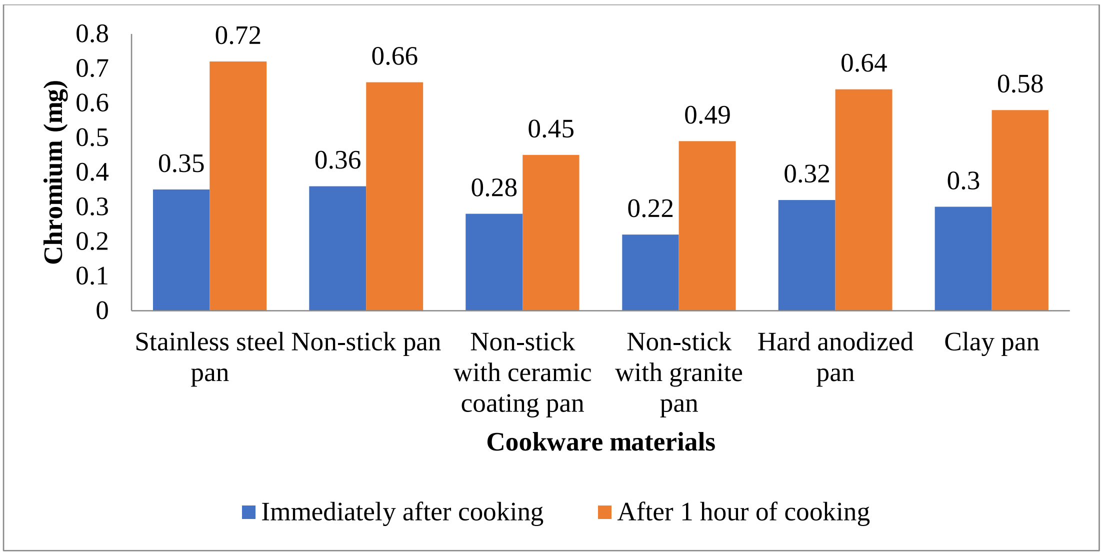


Fig. 5: Chromium toxicity of *jeera* rice in selected cookware materials

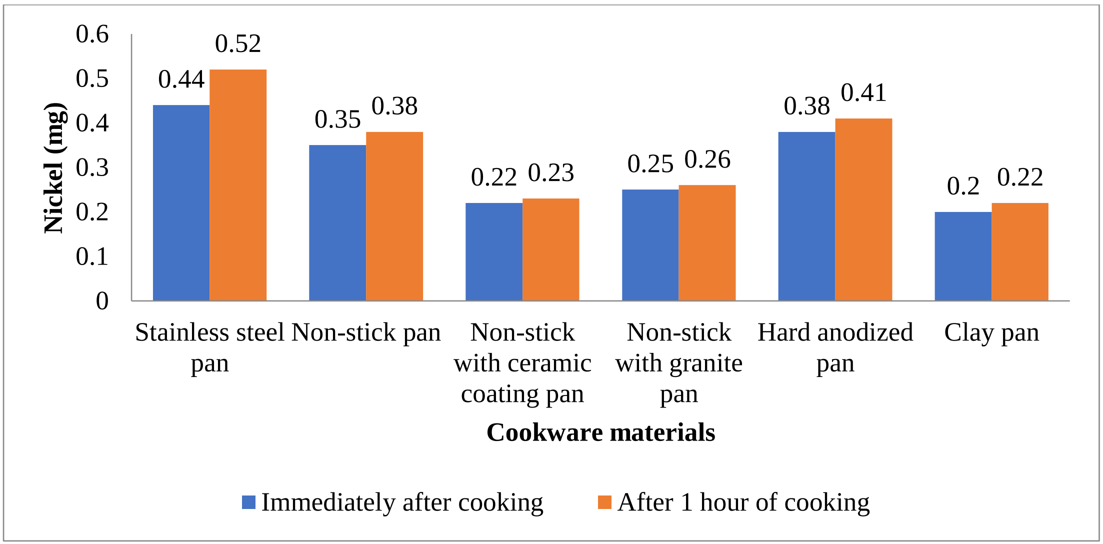


Fig. 6: Nickel toxicity of *jeera* rice in selected cookware materials

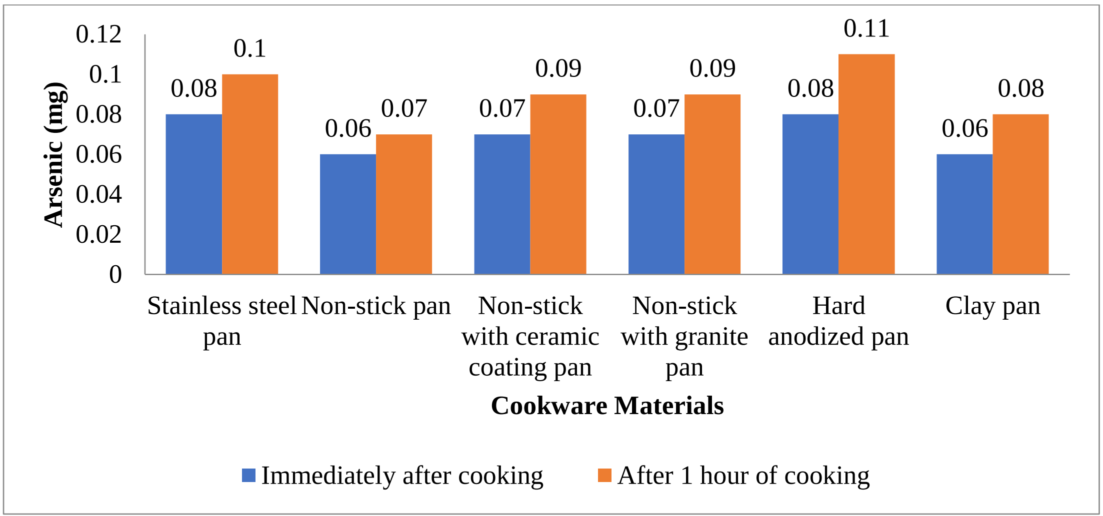


Fig. 7: Arsenic toxicity of *jeera* rice in selected cookware materials

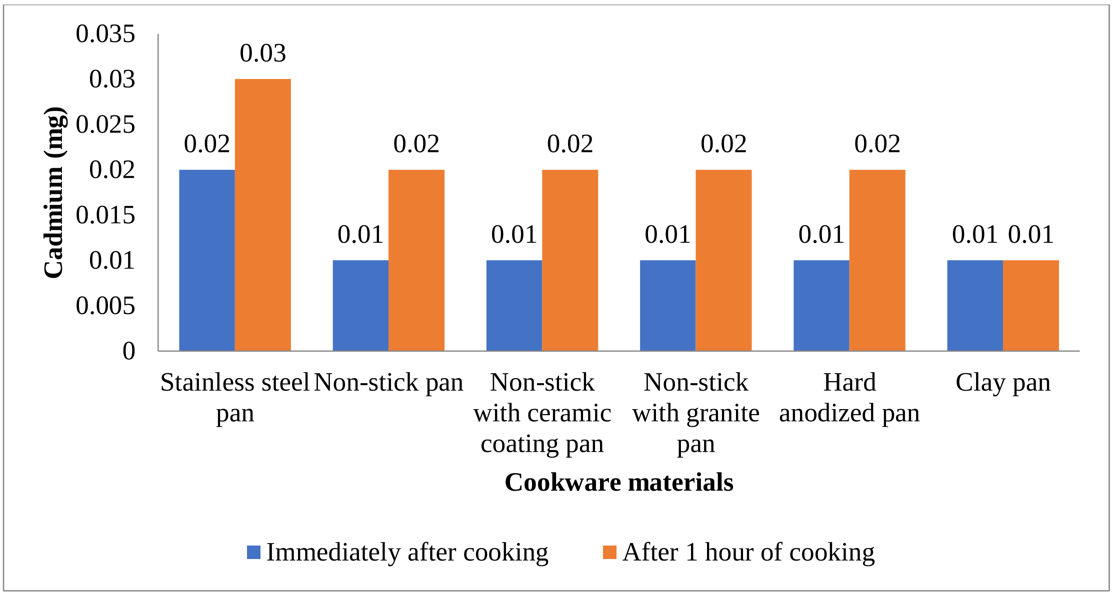


Fig. 8: Cadmium toxicity of *jeera* rice in selected cookware materials

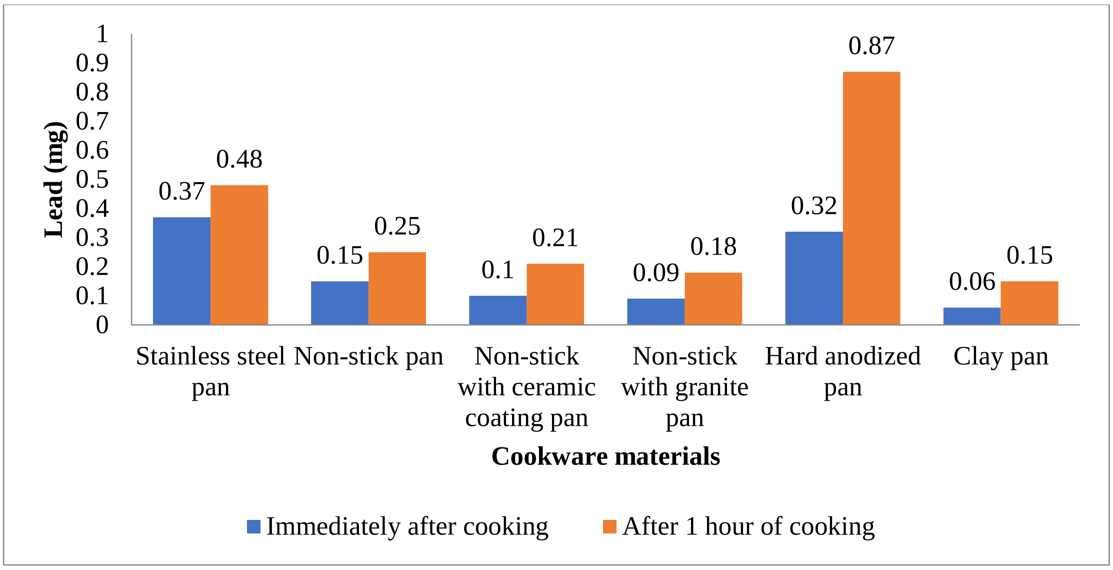


Fig. 9: Lead toxicity of *jeera* rice in selected cookware materials

4.3.7 Heavy metal toxicity of "potatoes with fenugreek leaves vegetable (dry)" prepared in selected cookware materials

In Table 4.18, the trace elements in Potatoes with fenugreek leaves vegetable (dry) in different cookware materials were depicted. As it was clear from the table that the chromium contents were found to be maximum in the potatoes with fenugreek leaves vegetable (dry) which was cooked in hard anodized (0.99 mg) followed by stainless steel (0.98 mg) and non-stick (0.93 mg). Minimum amount of chromium found in non-stick with ceramic coating pan (0.80 mg); whereas, after 1 hour of cooking higher content of chromium found in stainless steel pan (1.30 mg) followed by hard anodized pan (1.28 mg) and minimum found in non-stick with ceramic coating pan (0.94 mg). But it can be further seen that in all samples chromium contents were found to be more than the permissible limits i.e. 0.20 mg/day.

Table 4.18 Heavy metal toxicity of "potatoes with fenugreek leaves vegetable (dry)" prepared in selected cookware materials

Type of cookware materials	Chromium (mg)		Nickel (mg)		Arsenic (mg)		Cadmium (mg)		Lead (mg)	
	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking
Raw sample	0.19	-	0.25	-	-	-	-	-	-	-
Stainless steel pan	0.98	1.30	0.58	0.67	0.02	0.04	0.01	0.02	0.20	0.23
Non-stick pan	0.93	1.25	0.55	0.68	0.01	0.02	0.01	0.02	0.22	0.26
Non-stick with ceramic coating pan	0.80	0.94	0.39	0.43	-	0.01	-	0.02	0.19	0.20
Non-stick with granite pan	0.82	0.97	0.42	0.49	0.01	0.02	-	0.02	0.20	0.21
Hard anodized pan	0.99	1.28	0.41	0.47	0.01	0.02	0.01	0.02	0.26	0.28
Clay pan	0.81	0.96	0.30	0.31	-	0.02	-	0.02	0.15	0.18
Permissible Limits	0.05-0.20 mg/day		Safe but allergic		0.12 mg/ day		0.03 mg/day		0.3 mg/day	

It can be seen that maximum content of nickel was found in potatoes with fenugreek leaves vegetable (dry) in stainless steel (0.58 mg) followed by non-stick pan (0.55 mg); whereas, minimum amount of nickel was found in clay pan (0.30 mg). Further analysis of the data showed that after one hour of cooking maximum content of nickel was found in non-stick pan(0.68 mg) followed by stainless steel pan (0.67 mg) whereas, minimum amount of nickel was found in clay pan (0.31 mg).

The data showed that maximum arsenic contents were found in potatoes with fenugreek leaves vegetable (dry) which was cooked in the stainless steel (0.02 mg) cookware followed by non-stick with granite coating pan, non-stick and hard anodized pan (0.01 mg) which were recorded minimum amount of arsenic. Further it was observed from the data after one hour of cooking maximum arsenic content was found in stainless steel (0.04 mg)followed by non-stick, granite, hard anodized and clay cookware with 0.02 mg and minimum amount was found in ceramic cookware (0.01 mg).

Data in the table 4.18 further depicted that cadmium contents were found in potatoes with fenugreek leaves vegetable (dry) cooked in stainless steel, non-stick, and hard anodized cookware (0.01 mg). After one hour of cooking, the samples in all cookware found to be recorded equal amount of cadmium with 0.02 mg. However, the cadmium content were recorded across all cookware was satisfactory and within the permissible limit (0.03 mg/day).

The perusal of the data revealed that highest lead content found in hard anodized (0.26 mg) cookware and minimum was recorded in clay pans (0.15 mg). Further the data depicted that one hour after cooking maximum lead content was found in the hard anodized (0.28 mg) cookware followed by non-stick (0.26 mg) and stainless steel cookware (0.23 mg); whereas minimum content was found in samples that were collected in clay pans (0.18 mg). All cookware released lead with in the acceptable levels of 0.30 mg/day.

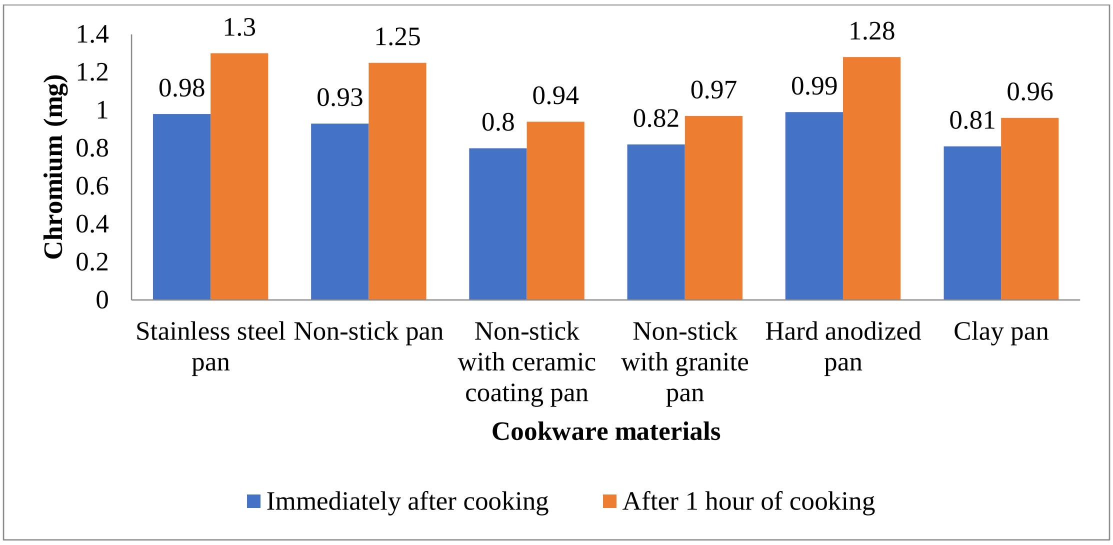


Fig. 10: Chromium toxicity of potatoes with fenugreek leaves vegetable (dry) in selected cookware materials

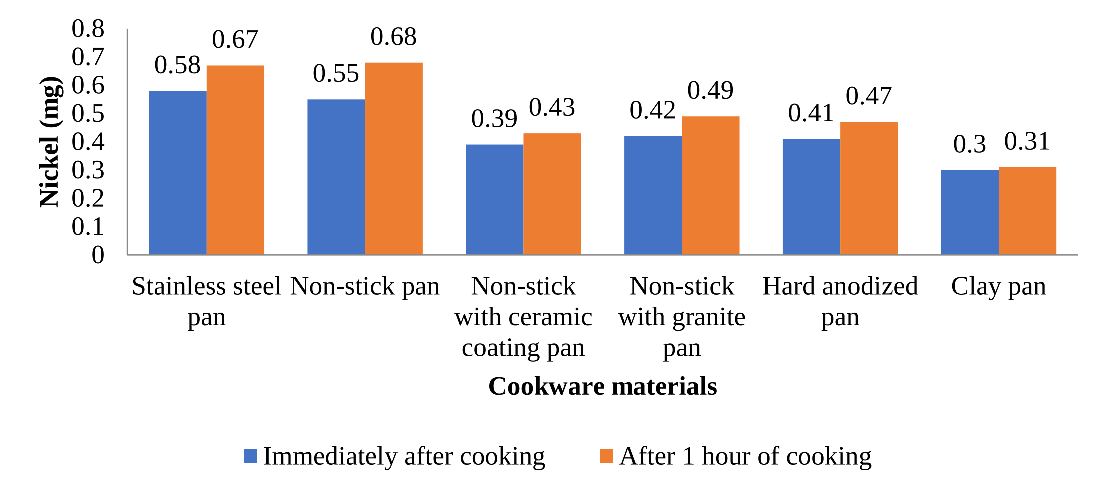


Fig. 11: Nickel toxicity of potatoes with fenugreek leaves vegetable (dry) in selected cookware materials

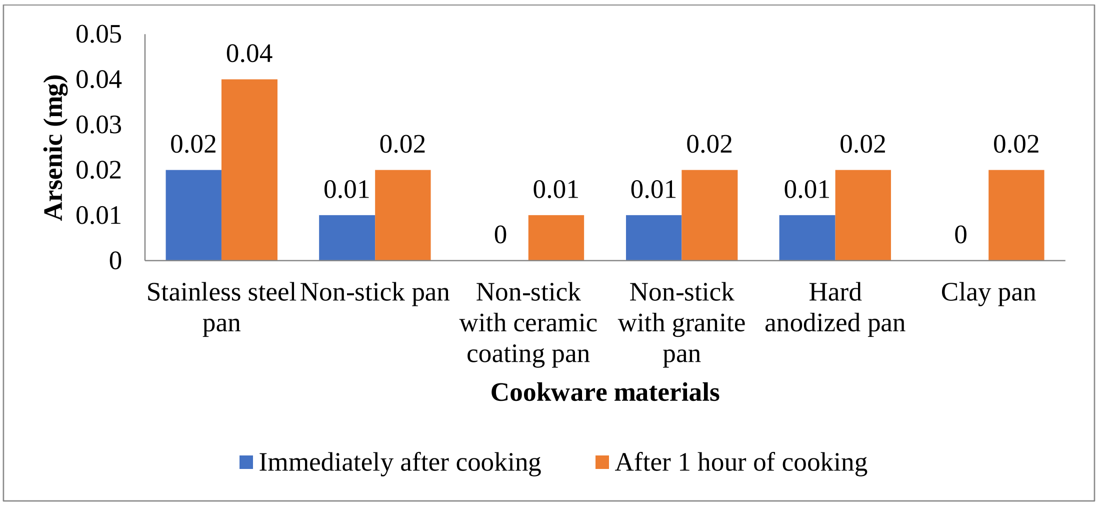


Fig. 12: Arsenic toxicity of potatoes with fenugreek leaves vegetable (dry) in selected cookware materials

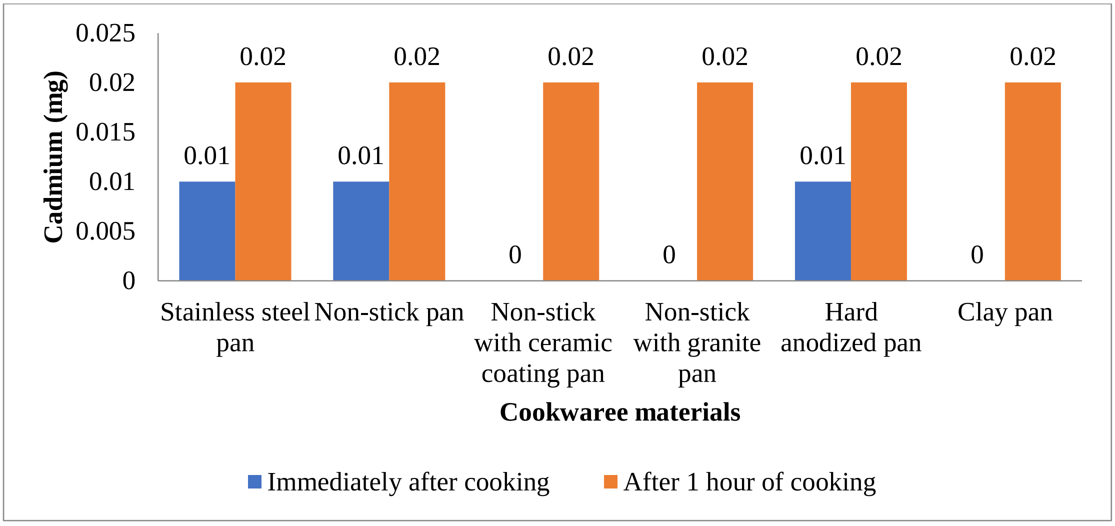


Fig. 13: Cadmium toxicity of potatoes with fenugreek leaves vegetable (dry) in selected cookware materials

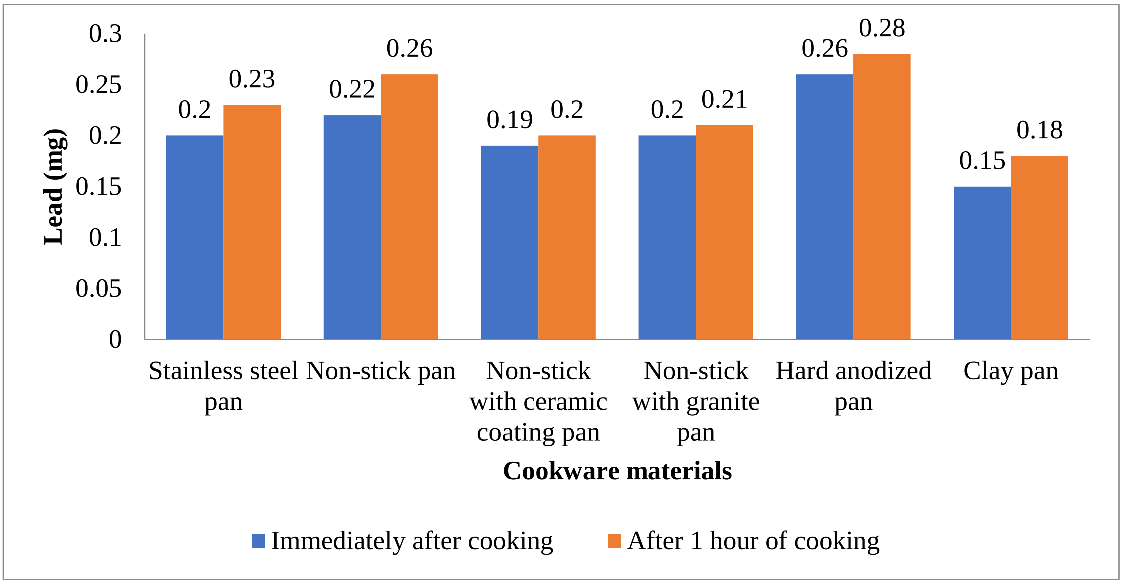


Fig. 14: Lead toxicity of potatoes with fenugreek leaves vegetable (dry) in selected cookware materials

4.3.8 Microbial estimation of cooked food samples

The food cooked in different cookware materials including *jeera* rice and potatoes with fenugreek leaves vegetable (dry) were tested in the laboratory with the help of Bacteriological Food Testing Kit (BFTK)

Samples were tested for food borne pathogens (*Escherichia coli, Staphylococcus aureus, Salmonella and Shigella spp.*) and emerging pathogens (*Yersinia enterocolitica, Aeromonas hydrophila, Campylobacter jejuni and bacillus cereus*) - identified on the basis of etiological agents isolated during routine sampling testing. The results are presented in table 4.19.

Microbiological study:

Along with appropriate nutrition, palatability and microbial safety, plays an important role in the food prepared in the different cooking ware. This is one of the major objectives that must be pursued by the manufacturer. It is important aspect in the reduction of food-borne pathogens in Ready-To-Eat (RTE) foods. If food is contaminated then it directly affect the human health, but the contaminated food contact surfaces are more critical. Cookware is having strong relationship with the risk assessment in food, these food contact surfaces play an important role in increase or decrease in the microbial contamination. The increase in microbial contamination might be due to the cross contamination from the other kitchenware. The reduction of microbial contamination might be of two major reasons, due to the application of heat during cooking or due to the presence of antimicrobial coatings on the surface. Temperature is one of the most important intrinsic factors that affect the growth of microbes and their inactivation in the different foods (Cepeda *et al* 2013).

Table 4.19 Microbial estimation of cooked food samples of *jeera* rice and potatoes with fenugreek leaves vegetable (dry) in different cookware

Cookware materials	***E.coli***	***Salmonella spp.***	***Staphylo coccus***	***Shigella spp.***	***Aeromonas hydrophilla***	***Yersinia enterococcus***	***Bacillus cereus***	***Listeria monocytogens***	***Campylo bacter spp.***	***Klebsiella pneumoniae***
Stainless steel pan	No single pathogen was detected									
Non-stick pan	No single pathogen was detected									
Non-stick with ceramic coating pan	No single pathogen was detected									
Non-stick with granite coating pan	No single pathogen was detected									
Hard anodized pan	No single pathogen was detected									
Clay pan	No single pathogen was detected									

From several decades, the work on different microbial models linked-up with temperature is analysing the process of risk assessment. Cooking is a very critical step, not only improves the nutritional properties but also destroys the food borne pathogens by giving assurance to the consumers (Pathare and Roskilly, 2016).The present study on the survival of ten major food borne pathogens in different six cookware which includes, stainless steel pan, non-stick pan, non-stick with ceramic coating, non-stick with granite coating pan, hard anodized pan and clay pan as shown in the Table 4.19.According to present study, no single pathogenic organism was observed on selected cookware after the food was cooked and kept in the cookware for six hours. This clearly showed that these cookware maintain the food safety after cooking. Similarly, Yoon *et al* (2008) studied and concluded that Salmonella and Listeria species were not identified on the cookware. According to Saada *et al* (2013), coliforms are present on the earthen pots, doesn't have *E. coli.* The survival rate of *L. Monocytogenes* on the stainless steel without any food residues was relatively low. In a study conducted by Allan *et al* (2004), it is concluded that stainless steel doesn't support the survival of *L. Monocytogenes.* In contrast, the total bacterial count on earthen cookware was observed as 9.6 × 105 cfu/ml (Afunwa *et al* 2019).Similarly, the total coliforms and heterophilic bacteria on the cooking pots were observed as 70 per cent and 65 per cent (Rakhshkhorshid *et al* 2016).Sometimes the growth of microbes on the different cookware in RTE foods might be due to the utilisation of unsanitised equipment and cross contamination. The studies on the cookware with different microbial analysis plays an essential role, which is a fundamental prerequisite to resolve many actions. Improvement in the cooking practices with different cookware or investigating the innovative cooking technologies helps to develop different RTE foods. This helps the consumer to make proper selection of cookware (Marzano and Balzaretti, 2013).The separation between the cooked and uncooked foods plays an important role in the reduction of cross contamination. Hazard Analysis and Critical Control Point (HACCP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) plays an important role in the improvement of microbial safety.

4.3.9 Comparison of market survey, household survey and laboratory experiments of cookware materials

Although, there are many cookware materials available in the market, most commonly materials used by the respondents were namely non-stick, non-stick with ceramic coating, stainless steel, non-stick with granite coating, hard anodized and clay pan. The physical characteristics such as heat conductivity and heat retention vary from each cookware materials. Hence, from the laboratory results, it was found that heat conductivity was observed better in hard anodized pan followed by non-stick with ceramic coating pan as it reaches to maximum heat when compared to all other selected cookware materials.

Table 4.20 Comparison of market survey, household survey and laboratory experiments of cookware materials

Availability of cookware materials in the market	Most commonly used by the respondents	Physical characteristics of cookware materials					Toxic contents in cooked food	Microbial contamination in cooked food
		Heat conductivity	Heat retention	Fuel consumption (in grams)*	Organoleptic Evaluation (Mean rank)*	Moisture content (in grams)*		
Non-stick Aluminium Stainless steel Cast iron Hindalium Hard anodized Non-stick with ceramic coating Stainless steel with copper base Stainless steel- Tri ply Non-stick with granite coating Aluminium with marble coating Brass Clay pan	Non-stick	178^{0} C	108^{0} C	31.20	**2**	**7.30**	Chromium (much above the permissible limits)	No single pathogen was detected
	Stainless steel	170^{0} C	**119^{0} C**	**29.00**	6	7.43	Chromium, Lead (much above the permissible limits)	
	Non-stick with ceramic coating	**180^{0} C**	**112^{0} C**	30.00	**1**	**7.25**	**Chromium (a little above the permissible limits)**	
	Non-stick with granite coating	179^{0} C	107^{0} C	30.50	3	7.33	**Chromium (a little above the permissible limits)**	
	Hard anodized	**182^{0} C**	109^{0}C	**29.75**	5	7.32	Chromium, Lead (much above the permissible limits)	
	Clay pan	175^{0} C	101^{0}C	30.50	4	7.35	Chromium (much above the permissible limits)	

***Readings for *Jeera* rice only are taken as results of both the cooked recipes were similar for all the selected cookware materials**

In terms of heat retention, stainless steel followed by non-stick with ceramic coating pan were found to be better as it retains heat for longer period of time when compared to other materials. Consumption of fuel was found minimum in stainless steel pan followed by hard anodized pan and non-stick with ceramic coating pan. In case of organoleptic evaluation, non-stick with ceramic coating pan found to be best as food cooked in it had good appearance, texture, taste, flavour and doneness followed by non-stick pan. Minimum moisture content was observed in non-stick with ceramic coating pan followed by non-stick pan. The nature of cookware materials and cooking process can increase heavy metals in the cooked food which leads to toxicity. Chromium and lead were found much above the permissible limits in stainless steel pan and hard anodised pan while chromium was found a little above the permissible limits in non-stick with ceramic coating pan and non-stick with granite coating pan and rest of all other heavy metals were within the permissible limits. No single pathogen was detected in any selected cookware materials this may be due to either temperature while cooking or antimicrobial treatments present on the cookware materials.

CHAPTER- V

SUMMARY

As a consumer, we have several expectations on food available which includes safe and hygienic food, wholesome with right nutritional content, protected from microbial contamination, intoxication and adulteration. Cooking is an inevitable part of our daily life. Home without cookware is un-imaginary. Technological advances during industrialization brought major changes in the kitchenware.

The adoption of the new cookware was slow due to the higher cost. Quality and innovative cookware materials with high quality finishes are available which are able to meet the consumer needs and demands. Proper selection of commonly used cookware materials can be a great help in resource saving as well as in contributing health of the family. Cookware selected for cooking should be durable, simple in design and of suitable size and shape.

Kitchen is one of the places which deal with phenomenon of heat conduction and heat retention in cookware materials. Every metal has its own distinct characteristics with respect to heat conductivity, heat retention, time taken and fuel consumption. Metal elements of these cookware materials may get dissolved in cooking when it comes in contact with food affecting the mineral contents of the food. These metal elements can have either positive or negative effects depending on the type and amount of metal used.

From time to time, concern is expressed over the possibility of pick-up of metals and their compounds from cookware used in the cooking of food and their possible adverse effects on human health and food quality. Toxicity of heavy metals is a serious problem through-out the world. Consumption of heavy metals through cookware acts as a slow poison in human body. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long term exposure of some metals may even cause cancer.

Metals are particularly toxic to the sensitive, rapidly developing systems of foetuses, infants and young children. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioural problems such as aggressiveness and hyperactivity. At higher doses, heavy metals can cause irreversible brain damage. Children may receive higher doses of metals from food than adults, since they consume more food for their body weight than adults.

Keeping in view the above points, present study entitled “Thermal Efficiency and quality of cooked food: Evaluation of cookware materials” has been undertaken with the specific objectives:-

1. To find out commonly available cookware materials for surface cooking.
2. To study the thermal efficiency of selected cookware materials.

3. To assess the extent of microbial and toxic contents in food cooked in selected cookware.

The methodology of the study was conducted in three parts:

i. Market survey

ii. Household survey

iii. Laboratory experiments

To achieve the above mentioned objectives, an interview schedule was prepared for the purpose of market survey. The information was collected about availability of cookware materials in different capacity and frequency of sale of cookware materials etc, to know the general trend of cookware materials.

For household survey, an interview schedule was prepared, pre-tested and finalized for data collection. The data were collected from homemakers by personal interview method. On the basis of household survey, most commonly used cookware materials and recipes were selected for laboratory experiments.

Laboratory experiments were conducted to study the trace of heavy metals in cooked food microbiological quality of cooked food in selected cookware materials. In laboratory experiments six cookware i.e. stainless steel pan, non-stick pan, non-stick with ceramic coating, non-stick with granite coating, hard anodized pan and clay pan and two commonly made recipes by the families i.e. *jeera* rice and potatoes with fenugreek leaves vegetable (dry) were selected for the laboratory experiments. Gas stove was used as heating unit. Heat conductivity of the selected cookware was tested by 500 ml of coconut oil in each cookware. The rise in temperature from 40^0C was noted down after every minute using a laboratory thermometer for 15 minutes. Similarly heat retention was tested by gradual lowering of the temperature per minutes from the highest temperature was recorded of each cookware. The lowering of the temperature was noted down for 20 minutes. Both the selected recipes were standardized and same procedure was followed on each cookware. The cooked recipes were evaluated and compared for the quality. A panel of five judges was selected for organoleptic evaluation of two recipes in terms of appearance, taste, colour, texture, doneness and overall acceptability. The evaluation was done by assigning the scores for food cooked. Every recipe was cooked twice in all selected cookware and the mean scores were used to formulate the results and fuel consumption of each cookware was noted down. Immediately after cooking, 15 gm of sample of cooked food was taken in petridish and second sample was taken after 1 hour of cooking. Each sample was dried in hot air oven for 48 hours at 70^0C. Wet digestion of dried samples was done to make the clear solution for testing heavy metals with the help of ICAP (Inductive Coupled Argon Plasma). Two recipes which were cooked in all the selected cookware materials were considered for microbial analysis. The samples were tested with the help of Bacteriological Food Testing Kit (BFTK). After cooking process, the food was kept in the same cookware for 6 hours and then 1 gram of sample from each cookware was aseptically added into the kits and incubated for 24-48 hours at 37^0 C. Then the results were noted down.

Major findings of the study

Market survey of the selected crockery stores revealed that stainless steel cookware was available in all the capacities at all selected crockery stores followed by aluminium at 80.00 per cent stores. The non-stick cookware material of more than 2000 ml capacity was available only at one crockery store. Cookware material of non-stick with ceramic coating, hard anodized, stainless steel with copper base, stainless steel-Tri ply and non-stick with granite coating was available in all the capacity at 60.00 per cent crockery stores.

All the selected cookware materials were available at all the selected crockery stores both with and without lid, but in case of aluminium, stainless steel, cast iron and non-stick with granite coating were available without lid at some crockery stores.

At all the crockery stores which possessed different cookware materials, each of the cookware material was available in all different thicknesses.

All the types of cookware materials were easy to care except cast iron cookware (only 20% reported easy care) and stainless steel with copper base as none of the shop owners reported easy care. Regarding burning of food in different cookware materials, almost all the cookware materials were least prone to food burn except for aluminium, stainless steel and cast iron cookware which are prone to food burn. Almost all the cookware materials available at selected stores had properly fixed handles and good in terms of equal distribution of heat except for cast iron cookware. All the available cookware materials irrespective of the metal were properly balanced.

Stainless steel was most frequently sold cookware followed by non-stick cookware by the selected crockery stores and aluminium with marble coating cookware was least sold as compared to other cookware materials.

Household survey revealed that majority of the respondents i.e. 61.67 per cent were in the age group of 41-50 years and 60.00 percent of the respondents had education upto graduation level and 73.33 per cent of the respondents belonged to size of family up to 4 members. Most of the respondents i.e. 50.00 per cent belonged to salaried class.

The maximum possession of different size of cookware materials was non-stick and stainless steel followed by non-stick with ceramic coating cookware. Small size of non-stick and stainless steel were possessed maximum i.e. 73.33 per cent by the households and 100.00 per cent of the respondents possessed medium size of non-stick cookware. Stainless steel cookware was maximum possessed in terms of large size by 40.00 percent respondents.

The most frequently used cookware by the households was stainless steel as 33.33 per cent use it thrice a day, 53.33 per cent use it twice a day and 13.33 use it once a day and second most frequently used cookware was non-stick as 66.67 per cent households use it twice a day and 33.33 per cent use it once a day. Non-stick with ceramic coating, hard anodized, stainless steel with copper base and non-stick with granite coating were mostly used once a day. Aluminium and brass cookware were less frequently used by the respondents.

Stainless steel was found to be used maximum for boiling vegetables by 93.33 per cent of the respondents. For cooking dry vegetables, non-stick cookware was found to be used maximum by 66.67 per cent respondents. Stainless steel with copper base cookware was mostly used for deep frying purpose by 33.33 per cent of the respondents. Non-stick with granite coating cookware was found to be used maximum for preparing *tarka*. For cooking curry vegetables, 80.00 per cent of the respondents were found to be used non-stick with ceramic coating cookware and clay cookware. About 53.33 per cent respondents are using non-stick with ceramic coating cookware maximum for heating vegetables. Cast iron was found to be used maximum for shallow frying by 46.67 per cent of the respondents. Non-stick and clay cookware was found to be used maximum for roasting purpose by 40.00 per cent of the respondents.

The respondents mostly used lid while cooking in cookware materials like clay pan, non-stick with granite coating, stainless steel- Tri ply and non-stick with ceramic coating (mean score 1.26 and 1.06 respectively) and while cooking in cookware materials like hindalium, stainless steel, aluminium with marble coating and cast iron mostly lid was not used (mean score less than 0.5).

In the laboratory study, the maximum heat conductivity was observed in hard anodized pan with the temperature rises up to 182^0C followed by non-stick with ceramic coating pan with 180^0C. In case of heat retention, stainless steel pan was found to be best as it retained maximum heat after 20 min of cooking with 119^0C followed by non-stick with ceramic coating with 112^0C.

From comparison of all the selected cookware materials, Stainless steel consumed minimum fuel for cooking *jeera* rice i.e. 29.00 gm followed by hard anodized pan and non-stick with ceramic coating pan i.e. (29.75 gm) and (30.00 gm) respectively; whereas maximum amount of fuel consumption was observed in non-stick pan (31.20 gm) followed by non-stick with granite coating pan and clay pan i.e. 30.50 gm fuel was consumed for both of the pans.

For cooking potatoes with fenugreek leaves vegetable (dry), the minimum fuel consumption was observed in stainless steel pan (33.80 gm) followed by hard anodized pan (33.90 gm) and non-stick with ceramic coating pan (34.00 gm).Maximum of fuel consumed for non-stick pan (35.00 gm) followed by clay pan (34.50 gm) and non-stick with granite coating pan (34.20 gm).

Regarding the organoleptic evaluation, non-stick pan with ceramic coating got the highest total score (Rank 1) in terms of appearance, texture, taste, flavour, doneness and overall acceptability followed by non-stick pan (Rank 2) whereas stainless steel scored least (Rank 6) for both the cooked recipes i.e. *jeera* rice and potatoes with fenugreek leaves vegetable (dry).

Minimum moisture content of *jeera* rice and potatoes with fenugreek leaves vegetable(dry) was observed in non-stick with ceramic coating pan (7.25 and 7.86 gm) respectively and maximum moisture content was found in stainless steel pan (7.43 and 9.11 gm) respectively.

From the results of elemental composition of *jeera* rice, the chromium was present above the permissible limits in all the selected cookware materials. Stainless steel had higher amounts of nickel. In hard anodized pan and stainless steel pan, lead was found above the permissible limits. Non-stick with ceramic coating cookware and clay cookware were found to have minimum toxic contents in cooked food when compared to all other cookware materials.

The food samples cooked in selected cookware materials were tested for food borne pathogens in laboratory. No single pathogen was detected in the cooked food samples.

Conclusion

On the whole, it is concluded that the commonly used cookware materials by the respondents for surface cooking were non-stick, stainless steel, non-stick with ceramic coating, non-stick with granite coating, hard anodized and clay pan.

Thermal efficiency of the selected cookware revealed that maximum heat conductivity was observed in hard anodized pan followed by non-stick with ceramic coating pan. Heat retention was found maximum in stainless steel pan followed by non-stick with ceramic coating pan. Fuel consumption was found minimum in hard anodized pan followed by non-stick with ceramic coating pan.

Organoleptic evaluation of the recipes cooked in selected cookware materials revealed that non-stick with ceramic coating pan got Rank 1 in terms of appearance, texture, taste, flavour, doneness and overall acceptability followed by non-stick with ceramic coating pan (Rank 2). Moreover, the moisture content was found minimum in food cooked in non-stick with ceramic coating pan.

It was observed that cooked food samples which were taken after 1 hour of cooking showed drastic increase in the trace metals, so it is suggested that immediately after cooking, food should be taken out in clear glass or other safe cookware. Consumption of cooked food in which trace elements was found maximum, if they consumed regularly can lead to serious health hazard if they retained in the human body. The reduction of microbial contamination can be due to application of heat during cooking and due to presence of antimicrobial coatings on the surfaces of cookware. This will result in consuming the healthy cooked food without contamination by the consumers.

Implications of the study

Due to the advancements in technology and competition in the market, different cookware materials for surface cooking are available which puzzle the homemaker in making the right choice. The findings of this study will provide the guidance to homemakers in selecting efficient cookware materials. It will help the homemakers for right selection of cookware materials in the market considering the safe to use and with minimum toxic content cookware which will result in maintaining the quality of food cooked in selected cookware.

Suggestions for the future study

1. Similar study can be conducted on other cookware materials using different heating units.
2. Research can also be conducted by cooking different recipes.

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APPENDIX -I

THERMAL EFFICIENCY AND QUALITY OF FOOD COOKED: EVALUATION OF COOKWARE MATERIALS

Market survey

1. **(a)Name of the store -**

   (b) Address of the store -

2. Specific information regarding the availability of cookware materials at selected crockery stores in different capacity for surface cooking

S.No.	Type of cookware materials for surface cooking	Capacity (ml) of cookware			
		250-500	500-1000	1000-2000	More than 2000

3. Availability of cookware materials at selected crockery stores 'with' and 'without' lid for surface cooking

S.No.	Type of cookware materials for surface cooking	With lid	Without lid

4. Availability of cookware materials with different thickness (Guage) for surface cooking

S. No	Type of Cookware materials for surface cooking	Thickness (Guage)				
		Less than 10	10-12	12-14	14-16	more than 18

5. Special features of cookware of different materials available for surface cooking

S.No	Type of Cookware materials for surface cooking	Special features of cookware materials				
		Easy care	Food doesn't burn	Proper fixing of handle	Proper balance	Equal distribution of heat

6. Frequency of sale of different cookware materials for surface cooking

S.No	Type of Cookware materials for surface cooking	Frequency of sale per day		
		Less than 10 pieces	10 to 20 pieces	More than 20 pieces

APPENDIX-II

Household survey

1. Demographic profile:

a. Name:

b. Age (years):

c. Address:

d. Education Qualification:

i. Matric ( )   **ii. 10+2 ( )**

iii. Graduate ( )   **iv. Post Graduate ( )**   **v. Any Other ( )**

e. Size of Family-

i. Up to 4 numbers   **ii. 5-7 numbers**   **iii. 8 & above numbers**

f. Occupation of the respondent-

i. Business……………….. iii. Service………………..

ii. Homemaker …………… iv. Any other……………...

2. Specific information regarding Possession of cookware materials by the respondents

S.No	Type of Cookware materials for surface cooking	Size		
		Small (250-500 ml)	Medium (500-1000 ml)	Large (1000-2000 ml)

3. Frequency of use of cookware materials by the respondents

S.No.	Type of Cookware materials for surface cooking	Thrice a day	Twice a day	Once a day	Alternate day	Weekly	Rarely

4. Type of food cooked in different cookware materials for surface cooking by the respondents

S. No.	Type of Cookware materials	Boiling vegetables	Cooking dry vegetables	Deep frying	Preparing tarka	Heating vegetables	Cooking curry vegetables	Shallow frying	Roasting

5. Frequency of use of lid of cookware materials by the respondents

S. No.	Types of Cookware materials for surface cooking	Frequency of use of lid		
		Always (2)	Sometimes (1)	Never (0)

Scoring: Always = 2

Sometimes = 1

Never = 0

APPENDIX-III

Heat conductivity of selected cookware materials for surface cooking for 15 min. (Temp. in ^{0}C)

Time in minutes	Stainless steel pan	Hard anodized pan	Non-stick pan	Non-stick with ceramic coating pan	Non-stick with granite coating pan	Clay pan
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Heat retention of selected cookware materials for surface cooking for 20 min. (Temp. in ^{0}C)

Time in minutes	Stainless steel pan	Hard anodized pan	Non-stick pan	Non-stick with ceramic coating pan	Non-stick with granite coating pan	Clay pan
20						
19						
18						
17						
16						
15						
14						
13						
12						
11						
10						
9						
8						
7						
6						
5						
4						
3						
2						
1						

Fuel consumption (in grams) of different cookware materials for selected recipes

S. No.	Cookware materials	Fuel consumption (gm)	
		***Jeera* rice**	**Potatoes with fenugreek leaves vegetable (dry)**
1	Stainless steel pan		
2	Non-stick		
3	Nonstick with ceramic coating pan		
4	Nonstick with granite coating pan		
5	Hard anodized pan		
6	Clay pan		

ORGANOLEPTIC SCORE CARD

Date_____________ Name of the judge _________________Name of recipe______________

Type of cookware materials	Appearance	Texture	Taste &Flavour	Doneness	Overall acceptability
	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
S_1					
S_2					
S_3					
S_4					
S_5					
S_6					

Scores for various parameters

5 Excellent

4 Very good

3 Good

2 Fair

1 Poor

Average moisture content (in grams) of selected recipes in different cookware materials

S. No.	Type of cookware materials	*Jeera* rice	Potatoes with fenugreek leaves vegetable (dry)
1.	Stainless steel pan		
2.	Non-stick pan		
3.	Non-stick with ceramic coating pan		
4.	Non-stick with granite coating pan		
5.	Hard anodized pan		
6.	Clay pan		

Heavy metal toxicity in *Jeera* rice prepared in different cookware materials

Type of cookware materials	Chromium (mg)		Nickel (mg)		Arsenic (mg)		Cadmium (mg)		Lead (mg)	
	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking
Raw sample										
Stainless steel pan										
Non-stick pan										
Non-stick with ceramic coating pan										
Non-stick with granite pan										
Hard anodized pan										
Clay pan										
Permissible Limits										

Heavy metal toxicity of "potatoes with fenugreek leaves vegetable (dry)" prepared in selected cookware materials

Type of cookware materials	Chromium (mg)		Nickel (mg)		Arsenic (mg)		Cadmium (mg)		Lead (mg)	
	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking	Immediately after cooking	After 1 hour of cooking
Raw sample										
Stainless steel pan										
Non-stick pan										
Non-stick with ceramic coating pan										
Non-stick with granite pan										
Hard anodized pan										
Clay pan										
Permissible Limits										

Microbial estimation of cooked food samples of *jeera* rice and potatoes with fenugreek leaves vegetable (dry) in different cookware

Cookware materials	*E.coli*	*Salmonella spp.*	*Staphylo coccus*	*Shigella spp.*	*Aeromonas hydrophilla*	*Yersinia enterococcus*	*Bacillus cereus*	*Listeria monocytogens*	*Campylo bacter spp.*	*Klebsiella pneumoniae*
Stainless steel pan										
Non-stick pan										
Non-stick with ceramic coating pan										
Non-stick with granite coating pan										
Hard anodized pan										
Clay pan										

APPENDIX- IV

Preparation of *Jeera* Rice

Ingredients

Rice	: 150g
Cumin Seeds	: 5 g
Oil	: 10 g
Salt	: 5 g
Water	: 3 glasses

Method

1. Wash the rice properly and soak in the water for half an hour
2. Put one table spoon of oil in a pan.
3. Add cumin seeds and cook it till light brown in colour and then add soaked rice in it.
4. When water starts boiling lower the flame
5. Turn the gas off when fully prepared by seeing its doneness.
6. Then keep it for a resting period of three minutes.

Preparation of potatoes with fenugreek leaves vegetable (dry)

Ingredients

Potatoes	: 300 g
Garlic	: 2 small cloves
Fresh fenugreek leaves	: 5 tbsp
Mustard Oil	: 1.5 tbsp
Turmeric	: 1 tsp
Salt	: according to taste
Whole dried large red chilli	: 3

Method

1. Chop the potatoes into pieces (1/2”) square.
2. Peel and cut the garlic cloves across into very fine slices.
3. Place the fresh fenugreek leaves in a fine sieve and wash in running water.
4. Immerse the leaves in a bowl of cold water, this freshens the leaves and releases their aroma.
5. Heat the oil and fry the sliced garlic until they turn into light brown colour.
6. Add turmeric and immediately followed by diced potatoes.
7. Stir them around for a short while over a lower heat flame.
8. Add the salt and then the fenugreek leaves.
9. Cook slowly over a lower heat flame with a pan covered on the top.
10. Stir occasionally so that potatoes do not stick to the bottom of the pan
11. When potatoes are fully cooked, put off the flame

VITA

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