Flaked rice is a major product in India. It is known by a number of names, including aval (Tamil), avalakki (Kannada), attakalu (Telugu), and poha (Hindi). It has played an important role in religious ceremonies for a very long time, and it is also one of the main breakfast items in the states of Maharashtra, Madhya Pradesh, Karnataka, Gujrat, and Rajasthan. Flaked rice is consumed raw or with milk. The common dishes made with it are onion poha and potato poha. The roasted, thick-flaked rice called chiwda or chura is used in namkins, which are a fried, crispy snack made with a mixture of cereals and pulses.

The production level of this rice product is not known exactly, but it has been indicated that about 10% of total rice production is utilized for flaked rice, expanded rice, and popped rice. In states where it is consumed as breakfast, there is more production and larger industries exist. In Karnataka, the flaked rice production centers are situated at Hubli, Bhadravathi, Davengare, Udipi, and Belgam. Gujrat, Navasari, Ahmedabad, Umreth, and Bavala are the locations of other major production centers, and Madhya Pradesh and Orissa are major producers as well. In other states, production is only at a cottage level.

For the purpose of this paper, the flaked rice industry was surveyed in the Indian states Tamil Nadu, Kerala, Karnataka, and Gujrat. The researchers investigated the various processes used to produce flaked rice and identified the problems faced in the field. The working parameters that were studied include the moisture content changes in the paddy, roasting temperature, temperature changes in the paddy, and yield details.

The researchers identified a number of potential upgrades for the flaked rice industry, including developing a method to achieve uniform moisture content of the soaked paddy and advancement of the temperature control systems of the roasters. Increased interaction with government departments and R&D institutions will further enhance the future of this rice product.

Flaked rice is a major product in India. The processes involved in creating flaked rice are cold or hot soaking, roasting, flaking, sieving, and packing. There are a number of potential upgrades for the flaked rice industry, including developing a method to achieve uniform moisture content of the soaked paddy and advancement of the temperature control systems of the roasters. Increased interaction with government departments and R&D institutions will further enhance the future of this rice product.

### Processing Methods of Flaked Rice

The processes involved in the production of flaked rice are cold or hot soaking, roasting, flaking, sieving, and packing (Fig. 1). At the cottage level, 50–300 kg of paddy are processed per day, while 1–5 and 10–20 metric tons are produced at medium- and large-scale processors, respectively. In flaked rice production, generally freshly harvested paddy is preferred, as it gives more whiteness. The moisture content and temperature at various processing steps of flaked rice are given in Table I.

#### Soaking and Conditioning

At the cottage level, soaking is done in metal drums or cement tanks (Fig. 2) for about 10–12 hrs, after which the water is drained. For larger processors, soaking

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<table>
<thead>
<tr>
<th>Process step</th>
<th>Sample</th>
<th>Duration</th>
<th>Moisture content (%)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soaking/conditioning</td>
<td>Paddy</td>
<td>2–24 h</td>
<td>25–33 (cold soaking)</td>
<td>Room temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hot soaking at some places</td>
</tr>
<tr>
<td>Roasting</td>
<td>Paddy</td>
<td>40–60 sec.</td>
<td>14–18</td>
<td>Roaster temperature (110–180°C)</td>
</tr>
<tr>
<td>Conditioning by water addition</td>
<td>Roasted paddy</td>
<td>--</td>
<td>16–19</td>
<td>Paddy temperature (105–120°C)</td>
</tr>
<tr>
<td>Conditioning</td>
<td>Roasted paddy</td>
<td></td>
<td></td>
<td>90–105°C</td>
</tr>
<tr>
<td>Flaking</td>
<td>Roasted paddy</td>
<td>20–60 sec.</td>
<td>14–16</td>
<td>80–95°C</td>
</tr>
<tr>
<td>Packing</td>
<td>Flaked rice</td>
<td>10–11</td>
<td></td>
<td>--</td>
</tr>
</tbody>
</table>
times range from 2–24 hrs. Many large-scale processors have replaced the cement tanks with vertical metallic tanks where the paddy is fed through surge bins from the top.

After the given soaking time, the water is drained and the paddy is conditioned for 2–3 hrs within the soaking tank or after heaping or spreading on a cement floor (Fig. 3). Hot water soaking is not practiced in the field, since it imparts color to the end product. The moisture content of soaked paddy reaches 25–33%, depending on climatic condition and the methods of soaking and preconditioning.

**Roasting**

Roasting, which can be performed with or without sand, is a strenuous, labor-intensive, and costly manual operation that requires skill and fine judgment to determine the appropriate termination point. Even a slight shift from the optimal roasting conditions may entail loss of yield caused by puffing of grains during roasting or breakage during flaking due to under-roasting (3). In Tamil Nadu, paddy is roasted in sand, whereas in Karnataka it is roasted in a fine silt medium.

For smaller cottage-level operations, roasting usually takes place in shallow iron pans (Fig. 4) placed on the hearth. The pans are made of thick iron material measuring 620 mm in diameter, 200 mm in height, and weighing about 17 kg. One to two kg of paddy is roasted at a time for about 1–2 min at 200–250°C.

In medium and large scale industries, roasting is usually performed by continuous roasters using a sand medium. The partial gelatinization of soaked paddy is achieved from roasting at 110–180°C for 10–60 sec. The soaked paddy is fed to the roaster by means of belt conveyors or by manually feeding the hopper. A medium-scale processor may have one such roaster and five edge runners. Larger processors would simply have more roasters and flaking units. Some of these larger processors have a precleaning facility, whereas in other places the raw paddy is soaked and the floating chaff and immature paddy are collected manually.

Mechanical roasters are available as batch types or continuous types. The roasters are operated either by electricity, diesel, or firewood. The electrical roaster (Fig. 5) consists of a circular heating coil over which a circular iron pan is mounted inside the metallic cover. Roasting is performed in batches with 8–10 kg of soaked paddy at about 200°C. The completion of roasting is indicated by the initiation of a popping sound of the roasted grains, after which the roasted paddy is discharged with a lever.

The continuous-type roasters are modified gram roasters (4) (Fig. 6). The roasters consist of outer and inner horizontal cylindrical drums. The inner drum is equipped with helical ribs to provide forward movement of the paddy and sand. As the paddy travels through the roaster, the moisture content is reduced by 8–12%. A mesh assembly is arranged such that the sand is sieved out and returned back towards the mouth of the roaster by means of helical ribs facing in the reverse direction. While the sand travels in the reverse direction, it is again heated by means of a heater locat-
ed beneath the roaster. The roasters found in the field are generally half-ton or one-ton-per-hour production models. In these types of roasters, sand is used as a medium for roasting. The roaster itself is heated by furnaces using either husks, sawdust, or furnace oil. The roaster and furnace are built with insulation fire bricks.

**Sieving and Conditioning**

At the cottage level, the roasted paddy is fed to the flakers, whereas, in medium-and large-scale systems it is moistened and conditioned to obtain different types of flakes, such as thick (~1 mm), medium (~0.6 mm), thin (0.55–0.3 mm), and very thin (<0.3 mm).

For the larger processors that operate the continuous type of roasters, the sand-roasted paddy is sieved in order to remove the adhering sand and impurities, such as awns (Fig. 7). After sieving, the roasted paddy is fed directly onto a screw conveyor, where the addition of water takes place at the beginning of the conveyor and uniform mixing occurs as it travels through the conveyor (Fig. 8). The amount of water added varies widely, mostly depending on the type of flaked rice processed, i.e., thin or thick. The approximate flow rate is 60–70 ml per minute. Due to the water addition, an increase of moisture content of 2–3% occurs. At the end of the screw conveyor, it is collected in bamboo or plastic baskets holding 1–2 kg roasted paddy and arranged as sets containing 4–12 baskets.

**Flaking**

At the household level, flaked rice is traditionally produced by hand pounding the soaked and roasted paddy using a pestle and mortar. At the cottage level and larger processing units, roasted paddy is collected in bamboo baskets and fed into an edge runner in 1–2-kg batches (Fig. 9). It is then flaked for 15–60 sec, depending on the quality of flaked rice. Thin flaked rice is obtained from longer running times, i.e., for 60 sec.

Edge runners (Fig. 10) are batch-type flaking machines with the capacity to flake 50, 100, and 140 kg/hr of paddy. In edge runners, the paddy is pressed in between the body of the edge runner and the flaking roller (Fig. 11). The husk and bran come out through the perforated mesh at the base of the edge runner. The remaining husk parts and bran that continue along with the flaked rice are cleaned by manual winnowing or by using a sieve shaker. After completion of flaking, the flaked rice is scooped out by hand and collected in wide-mouthed, shallow bamboo baskets.

In some places, the flaked rice obtained from the edge runner is again pressed and flattened in roller flakers to further reduce the thickness. Roller flakers designed by Central Food Technological Research Institute (Mysore, Karnataka, India) consist of two cylindrical rollers (Fig. 12). The roasted paddy is shelled and polished and then fed in between the rollers, in which it is pressed and flattened. The reduction in thickness is accomplished by passing the paddy through the set of rollers in sequence and pressing the flakes for further flattening. The gap between the two rollers is maintained by pressure. In medium- and large-scale industries, different types of flakes are produced. The end products are categorized according to the thickness of the flakes (Table II).

**Sieving and Packing**

The flaked rice is sieved in a sieve shaker in order to separate small, broken, powdered material and lumps (Fig. 13). The graded flaked rice is collected in heaps and turned from time to time until cool (Fig. 14). The thick flaked rice requires drying in order to reduce the moisture content before packing. After this, the flaked rice is packed directly into gunnies or in polyethylene bags inserted in gunnies. (Fig. 15). Different packing systems are in practice, such as 5, 45, and 50 kg bags depending on the requirements of the local market and the quality and type of flaked rice. The shelf life of the thick type of flaked rice is less than the medium and thin types as it contains more moisture and undergoes less polish than the other grades.

**Yield of Flaked Rice**

Generally 55–70% of yield is obtained in the field depending on the variety, quali-

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**Table II. Different types of flakes based on thickness**

<table>
<thead>
<tr>
<th>Type of flakes</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thick</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>Thin</td>
</tr>
<tr>
<td>4</td>
<td>Very thin</td>
</tr>
</tbody>
</table>

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Fig. A.  
Fig. 9. Flaking in edge runner.  
Fig. B.  
Fig. 10. Edge runners.  
Fig. 11. Edge runner (inner view).  
Fig. 12. Roller flaker.  
Fig. 13. Grading of rice flakes and separation of lumps and broken rice.
ity of paddy, processing conditions, and the type of flaked rice processed. Different states are using different paddy varieties, such as Adt 38, Co 43, IR 64, and TRY 1 in Tamil Nadu and IR 8, Jaya, and IR 64 in Karnataka, and IR 8 and Gurjari in Gujrat.

Marketing
The flaked rice is usually sold at local markets or to neighboring states. For instance, the flaked rice produced in Karnataka has a market at Tamil Nadu, Kerala, and other states. Likewise, the product from Gujrat is sent to Madhya Pradesh, Rajasthan, Maharashtra, and other southern states. In Kerala, the flaked rice obtained from red rice varieties is preferred. In the future, the potential for exporting flaked rice can be explored.

Problems
The most common problems identified with flaked rice are popping of the paddy during roasting, fly ash pollution due to fuel such as husk and sawdust, and dust pollution due to fine bran and flake powder created while running the edge runner. The operators running edge runners generally stand all day. The quality of flaked rice depends greatly on their experience and the amount of effort they put into flaking. Hence, making seating arrangements for edge runner operators would reduce their drudgery and improve the quality of life, which would reflect on the quality of flaked rice.

Fig. 14. Aerating graded rice flakes.

Fig. 15. Packing of rice flakes in polyjute gunnies.
The extent of popping can be minimized by optimizing parameters like soaking duration, roasting time, and temperature. Ananthachar et al. (1) reported that paddy soaked at 70°C for 18 hours gave 64.6% yield and 3% broken. Similarly, a maximum yield of 63.9% of flakes without lumping was obtained at a roasting temperature of 260°C with 3% broken. However, new optimal soaking and roasting temperatures need to be developed since the industry is predominantly using cold soaking in order to get whiter flakes.

Shankara et al. (5) improved the existing edge runner by introducing an additional idle-roller similar to that of the idle-roller already available with the machine. It reduced the flaking time from 60 to 40 sec. and reduced the breakage from 5 to 3%, which increased the yield of rice flakes from 65 to 67%. The continuous flaking system is another important development in this field. In the present type of flaking machinery, i.e., edge runners, an increase in capacity can be achieved only through adding more flaking units.

Conclusions
At present, flaked rice production needs to be standardized. Wide variations in temperature and moisture were observed during soaking, conditioning, before and after roasting, after moisture addition, and before flaking. Potential system upgrades, such as an alternative pollution-free fuel, continuous flaking systems, and design modifications to avoid injury to workers, are needed to improve and strengthen the quality and quantity of flaked rice production. Increased interaction with government departments and R&D institutions as well as increased knowledge regarding the potential for exporting flaked rice products will further enhance the future of this product. Since the current process is traditional, future entrepreneurs must be culturally aware and scientific process control methods must be involved.

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References

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