ABSTRACT

Cooking with traditional cookstoves using biomass fuel is a popular practice in rural parts of most low-income countries. To overcome the barriers and challenges associated with the implementation, uptake, and continued use of improved cookstoves, a comprehensive strategy that considers factors relating to the user's socio-economic, cultural, and cookstove design specifications is necessary. The study was conducted in the region Gaindi Khata hamlet in Haridwar, Uttarakhand where improved cookstoves had previously been introduced to homes. Here, the popular designs of biomass traditional cookstoves used in the village, such as forced draft and natural draft, were selected to conduct cooking tests and determine which cookstove among them performed the best. The testing protocols for testing of cookstoves, namely ISO 19867-1:2018(E) (International Organization for Standardization), BIS (Bureau of Indian Standards), and CCT (Controlled Cooking Test) testing methodologies, were followed for the cookstove performance test. The Weighted Sum Method (WSM), a multi-criteria decision analysis, was used to determine the optimal cookstove in this study based on the cookstove performance criteria such as cooking time, specific fuel consumption, CO (Carbon monoxide) and $PM_{2.5}$ (Particulate matter) emissions, capital cost, and cost of fuel saving. During rice cooking, the highest levels of $PM_{2.5}$ emissions were found in cookstoves in ND (Natural Draft) and TCS (Traditional Cookstoves), and the highest CO emissions in TCS and ND. In contrast, it was found that during the roti cooking test, the FD (Forced Draft) cookstove produced the maximum emissions of CO and $PM_{2.5}$, followed by the TEG (Thermoelectric Generator) cookstove. According to the laboratory cookstove test results for thermal efficiency, cookstoves of the FD type had the maximum efficiency, followed by those of the TEG, TCS, and ND types. The WSM analysis indicated the FD cookstove to be the most ideal for preparing rice, and the TCS cookstove as ideal for cooking roti. Since the tests were carried out under simulated conditions to estimate the performance and concentrations of emissions in the user

kitchen, the study sheds light on the appropriate cookstove to be implemented for the targeted communities. To analyse why improved cookstoves were not adopted by households in rural communities, a longitudinal survey was conducted after two years. Applying the Behaviour-Change Wheel (BCW) helped to identify interventions that might help overcome the behavioral obstacles to adoption, and the Capability, Opportunity, Motivation-Behaviour (COM-B) framework was adopted to explain the factors why. Physical barriers to continuous usage were their short lifespans without maintenance, their narrow fuelwood inlets, the presence of only one hob, and their suitability for only low- or slow-temperature heating. The unawareness of the users of the health advantages of improved cookstoves over traditional cookstoves, as well as certain user-experience hurdles, were identified as barriers to use. This emphasized the need for incorporating users in the co-design process for the upgraded cookstove.

In the fourth objective, development of a household-scale improved cookstove with an output power rating of 3 kW was carried out using an iterative design method. Three prototype cookstoves were tested namely SC1, TS10, and TS5 cookstoves were developed and tested under both natural and forced draft conditions. Cookstove SC1 was provided with a straight combustion chamber, while TS10 and TS5 cookstoves were provided with a throat section of radius 10 cm and 5 cm at a height of 0.5 of the total cookstove height. According to laboratory testing, the cookstoves with the highest thermal efficiency were those with forced draft, achieving 32–36%, 25–28%, and 20–13% for models SC1, TS10, and TS5, respectively. Heat transfer studies confirmed that the cookstove SC1 had the maximum heat gained by the cooking pot, followed by TS10 and TS5. Furthermore, the cookstove SC1's enhanced heat transmission efficiency suggested a larger surface area exposed to combustion gases from the cooking pot. Cookstoves with forced draft settings produce lower emissions, according to emission analysis. Under natural draft conditions, SC1, TS10, and TS5 operated at CO, 7.09, 8.12, 129.79, 113.24, and 171.20 mg/MJd; under forced draft conditions, CO, 6.32, 6.05, and 6.88 g/MJd, and $PM_{2.5}$,

69.80, 110.32, and 84.37 mg/MJd, were recorded. According to the study's findings, designing cookstoves with an iterative method can produce highly efficient appliances with minimal CO and $PM_{2.5}$ emissions while also considering user feedback.