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Full Length Article

Utilization of apricot seed in (co-)combustion of lignite coal blends: Numeric optimization, empirical modeling and uncertainty estimation

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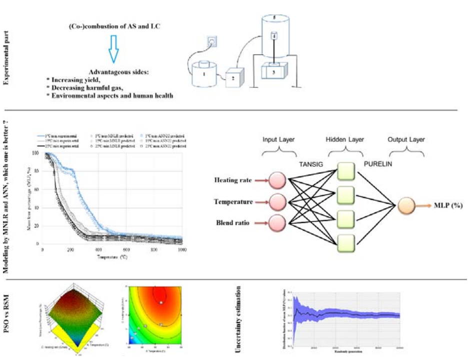
GRAPHICAL ABSTRACT



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ABSTRACT

Utilization of apricot seed (AS) in lignite coal (LC)-based (co-)combustion process was aimed in the present study considering the apricot production capacity of Turkey. By this way, an alternative and also ecofriendly way was suggested for coal-based energy production plants located in Turkey. This purpose was tested by thermogravimetric analyses to demonstrate the advantageous sides of AS in reduction of ash amount and also environmental aspects based on harmful gases. The other important contributors of present study was the comparison of both statistical modeling and numeric optimization techniques for maximization of mass loss percentage (MLP, %) in response to (co-)combustion process. For this purpose, multiple non-linear regression (MNLR) and artificial neural network (ANN) models as data-driven modeling techniques, and response surface methodology (RSM) and particle swarm optimization (PSO) as numeric optimization approaches were utilized. Results demonstrated the accuracy of ANN and PSO in prediction of MLP (%) and optimization of operating conditions of (co-)combustion of AS and LC, respectively. Finally, Bayesian approach was applied to the best-fit MNLR model to identify the uncertainties in predictors of proposed model. Bayesian was found quite effective in identification of uncertainties that were not possible to be captured through deterministic ways.

1. Introduction

Increasing energy consumption has triggered a search for novel energy resources and technologies in recent years. Accordingly, several alternative energy resources have been investigated to decrease the harmful effects of fossil fuels such as CO_2, SO_x, and NO_x emissions from coal-burning energy production plants. Hazardous effects of CO_2, SO_x, and NO_x emissions coming from energy production plants depending on

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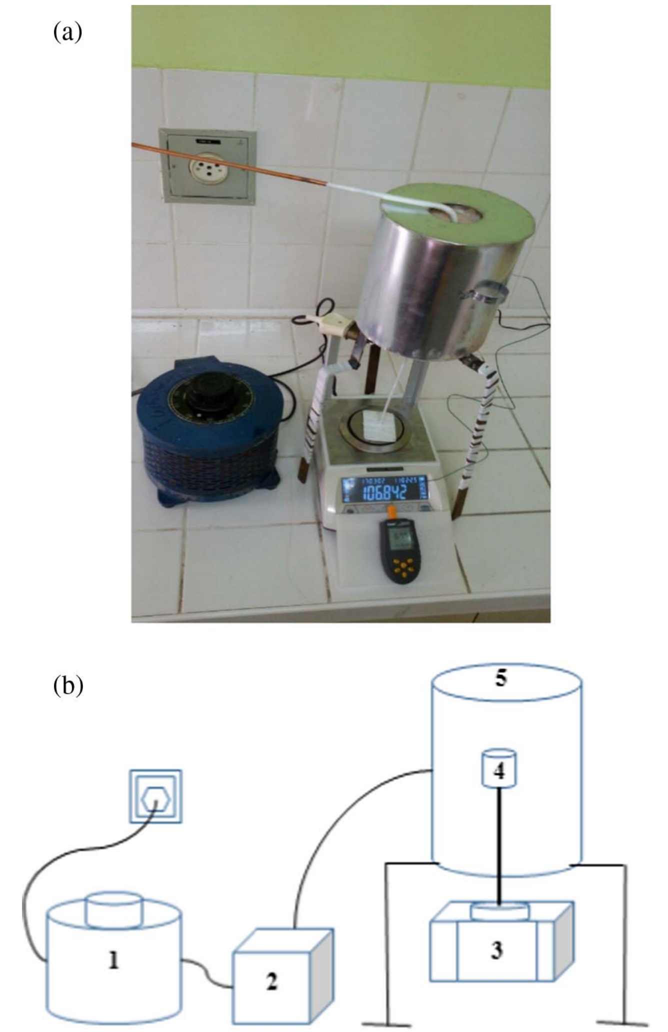

Fig. 1. (Co-)combustion process of AS and LC (a) experimental setup (b) schematic diagram (potentiometer (1), temperature controller and thermocouples (2), mass scale (3), sample basket (4), combustion system (5)).

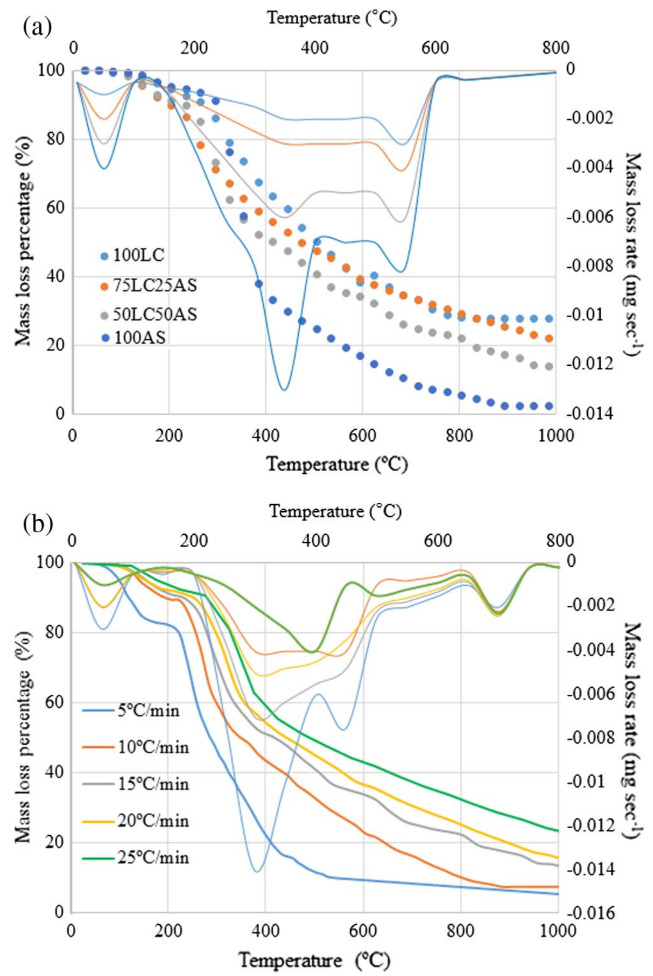

Fig. 2. Effects of (a) blend ratio and (b) heating rate on mass loss percentages and rate in response to (co-)combustion process.

coal combustion have been pointed out by many researchers correspondingly. Thus, this issue has gained a necessity to be addressed considering the environmental aspects and human health [1–5].

Turkey has a great potential to use agricultural byproducts in the co-combustion process as a result of the production of hazelnut, walnut, peanut, cotton seed, and sunflower. Apricot can be also added to this list considering the production capacity of 13,000 tons per year. Approximately 90% of this amount is supplied by the Malatya Province where vast amounts of apricot seeds (AS) are produced by local factories in the processing of apricots. Although storage and disposal of AS causes an environmental problem, there exists no study on reuse of AS with lignite coal (LC) in co-combustion in order to reduce both hazardous effects of AS disposal and coal combustion. By this way, reducing both hazardous effects of storage of AS (environmental aspects) and coal combustion (harmful gas emissions) can be possible [6–10].

Various statistical approaches have been used to predict different response variables of (co-)combustion systems, to obtain optimal operating conditions, and to capture uncertainties in predictors of proposed models [11,12]. Multiple (non-) linear regression (M(N)LR) [13,14], artificial neural networks (ANN) [15–17], response surface methodology (RSM) [18–20], artificial immune system (AIS) [21], particle swarm optimization (PSO) [22,23], Monte Carlo (MC) [24], and Bayesian approach (Markov Chain-interacted MC) [25] simulations are the most common used techniques in related literature. Although advantageous, theoretical basis, and application areas of these techniques have been extensively reported by many researchers [13–25], a comparative study for these techniques has not been carried out. A comparison study between these commonly used techniques of MNLR and ANN (1), RSM and PSO (2) may guide researchers and lead the selection of relevant techniques [13–25].

As a result, the main purposes of the present study can be listed as

Table 1
Ultimate and proximate results of AS and LC (on dry basis).

Sample	Ultimate analyses (wt.%)					Proximate analyses (wt.%)				Lower heating values (kcal kg^{-1})
	C	H	O	N	S	Moisture	Volatile matter	Ash	Fixed carbon*	
Lignite coal (LC)	67.1	12.4	5.5	1.2	13.8	21.4	38.3	27.8	12.5	2.7
Apricot seed (AS)	59.8	5.1	29.6	0.2	5.3	27.5	43.7	2.5	26.3	3.2

* Calculated by difference.