

# Supplementary Materials

**Table S1.** Sown areas, gross yields and yields of flax (seeds) and straw (fiber) in the Republic of Kazakhstan (2013–2022).

Year	Harvested Crop Area	Yield of Flax (Seeds)	Gross Harvest of Flax (Seeds)		Yield of Straw	Gross Harvest of Straw	
	ha	c/ha	Centner	Tons	c/ha	Centner	Tons
2013	384.3	7.7	2950.2	295.0	11	4227.3	422.7
2014	556152.0	7.6	4199572.6	419957	10.8	6006441.6	600644
2015	622544.9	7.9	4913894.4	491389	11.3	7034756.2	703475.6
2016	633614.64	8.9	5617708.2	561770	12.7	8046905.4	804690.5
2017	858657.0	8.0	6833375.2	683337	11.4	9788689	978869
2018	1076890.9	8.7	9335328.8	933532	12.4	13353436	1335343
2019	1245037.9	8.1	10072441.4	1007244	11.5	14317937	1431793
2020	1342518.0	7.9	10582470.0	1058247	11.3	15170453.4	1517045
2021	1366068.0	5.7	7755680.5	775568	8.1	11065150.8	1106515
2022	1345157.1	6.3	8456421.6	845642	9.0	12106413.9	1210641

**Table S2.** Results of measuring the breaking force F (kN).

Sample	Material: 40 g, Alkaline Treatment		Material: 45 g, Nitric Acid Treatment		Material: 40 g, Nitric Acid Treatment	
	1 Batch of Samples	2 Batches of Samples	3 Batches of Samples	4 Batches of Samples	5 Batches of Samples	6 Batches of Samples
1	0.10758	0.11131	0.06839	0.06385	0.19968	0.18490
2	0.09269	0.10280	0.07826	0.04796	0.19222	0.14563
3	0.08125	0.09987	0.08314	0.06361	0.16670	0.17091
4	0.10555	0.10254	0.07470	0.06159	0.19596	0.16964
5	0.10064	0.09641	0.07039	0.06099	0.19115	0.16772
6	0.10203	0.09478	0.05606	0.05905	0.18712	0.14134
7	0.11817	0.09713	0.04481	0.06814	0.19060	0.19201
8	0.10503	0.09415	0.08676	0.07820	0.15667	0.19128
Mean	0.079106	0.101618	0.070314	0.062924	0.185013	0.170429
The standard deviation of repeatability	0.007195	0.010904	0.014014	0.008505	0.015113	0.019195
Ratio of mean square deviation, %	9.095787	10.73061	19.93028	13.51629	8.168861	11.26306

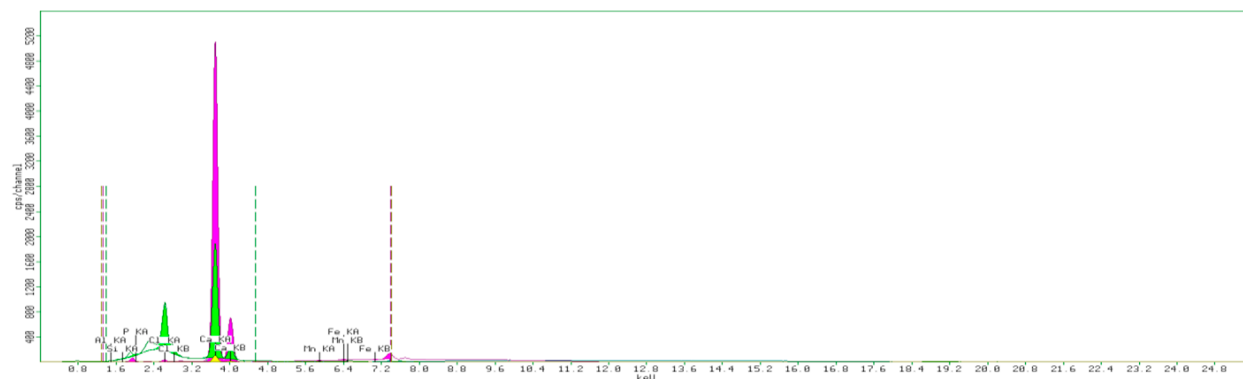
## S1. Identification of mineral elements by X-ray phase analysis

X-ray phase analysis for different types of papers determined the presence of all metals in the dry samples (Table S3). The X-ray spectra of the samples of different papers are shown in Figure S1.

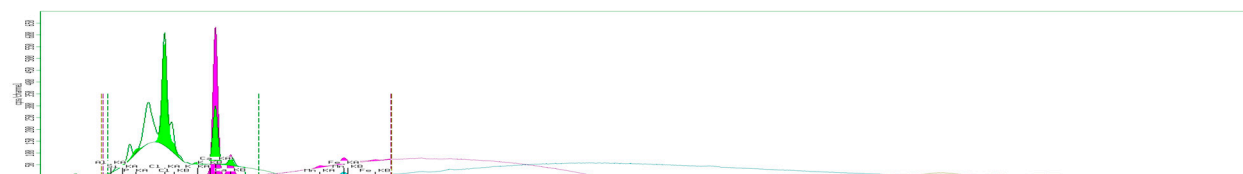
**Table S3.** X-ray phase analysis of minerals for different types of papers.

Sample	Content of Chemical Elements, %										
	Al	Si	P	Cl	Ca	Mn	Fe	K	Zn	S	Cu
Sample #1 Control	0.028	0.063	0.037	0.299	17.74	0.002	0.022	-	-	-	-
Sample #2 (flax straw treated with 30% NaOH)	0.038	0.055	0.07	0.057	2.318	0.014	0.05	0.027	-	-	-
Sample #3 (flax straw treated with 20% NaOH)	0.038	0.046	0.05	0.059	1.734	-	-	0.025	-	-	-
Sample #4 (flax straw treated with 1% HNO3 and 25% NaOH)	0.221	0.131	0.075	0.103	1.12	0.004	0.21	0.05	0.013	-	0.002
Sample #5 (flax straw treated with 4% HNO3 and 25% NaOH)	0.568	0.123	0.804	0.1	0.834	-	-	0.032	0.005	0.03	-
Sample #6 (wheat straw treated with 25% NaOH)	0.443	0.193	0.064	0.178	2.775	-	0.057	1.196	0.005	-	-

Sample #7 (rice straw treated with 25% NaOH)	0.015	0.817	0.307	0.145	0.658	-	0.029	0.481	0.001	0.136	-
Sample #8 (cardboard)	0.092	0.174	0.238	0.245	1.803	-	0.147	0.188	0.005	0.453	-



Sample #1 Control



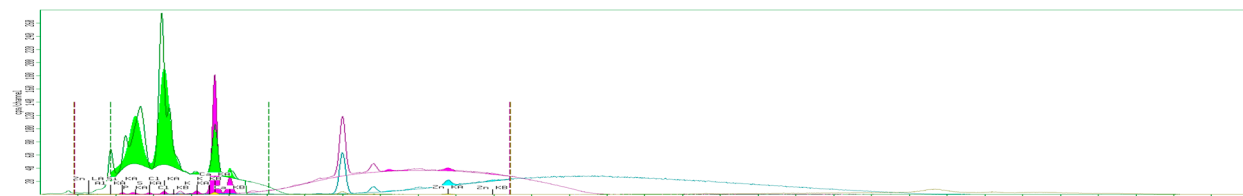
Sample #2 (flax straw treated with 30% NaOH)



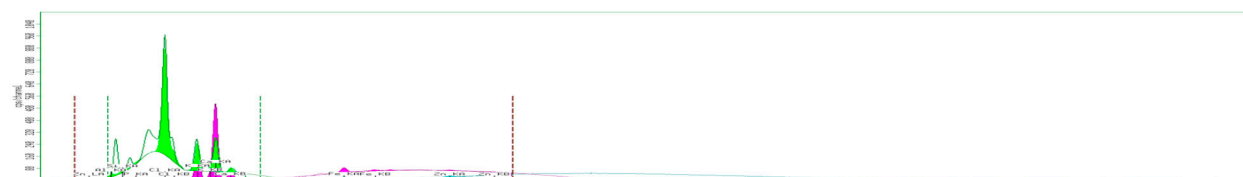
Sample #3 (flax straw treated with 20% NaOH)



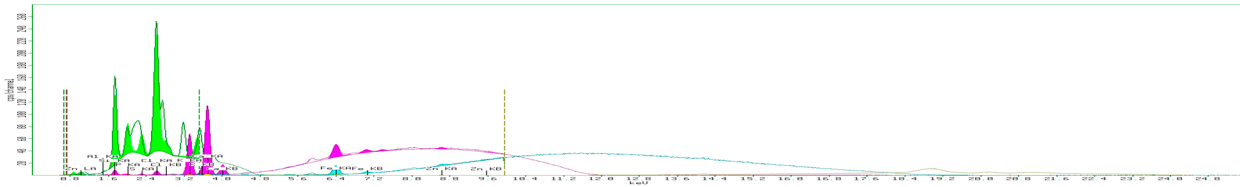
Sample #4 (flax straw treated with 1% HNO<sub>3</sub> and 25% NaOH)



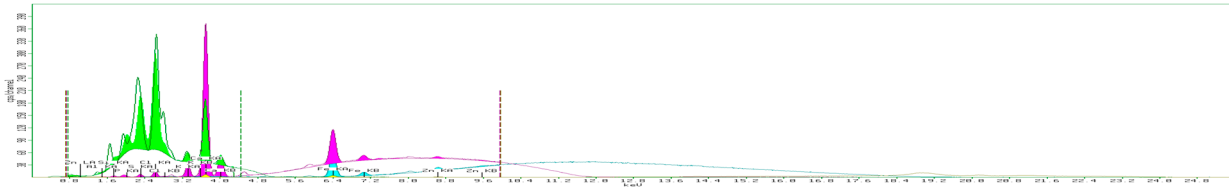
Sample #5 (flax straw treated with 4% HNO<sub>3</sub> and 25% NaOH)



Sample #6 (wheat straw treated with 25% NaOH)



Sample #7 (rice straw treated with 25% NaOH)



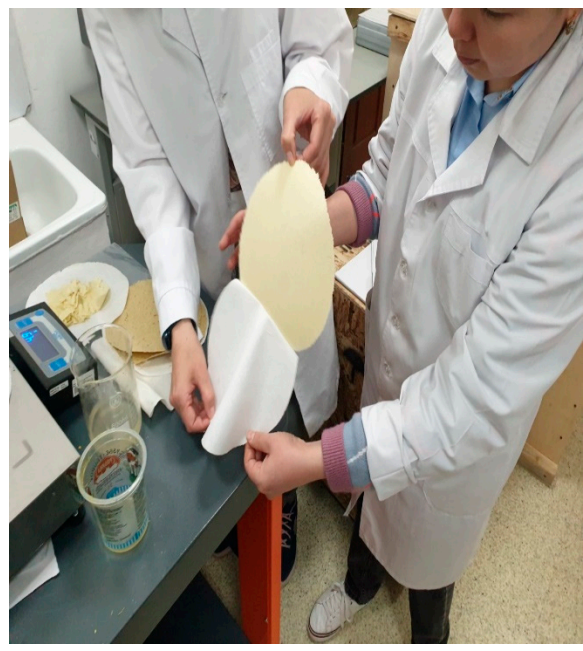
Sample #8 (cardboard)

**Figure S1.** X-ray spectra of samples of different papers.

Flax straw treated with 30% NaOH showed the highest amount of calcium (Ca), which affects the strength of the material and the least amount of chlorine, making it a more environmentally friendly product.

## S2. Photo Reports on Obtaining Environmentally Friendly Packaging Material





**Figure S2.** Boiling straw in a water bath.