BAB 5
KESIMPULAN DAN SARAN

5.1. Kesimpulan

Kegiatan penelitian yang dilakukan menghasilkan beberapa kesimpulan. Adapun kesimpulan yang dihasilkan adalah sebagai berikut.

1. Proses *direct carbonization* menghasilkan *yield* produk *N-doped hard carbon* dengan *yield* 22,67% untuk rasio pati:urea 1:1, serta 27,30% untuk rasio massa pati:urea 1:2. Sedangkan, proses sintesis melalui HTC memiliki *yield* produk 7,39% untuk rasio pati:urea 1:1, dan 6,70% untuk rasio pati:urea 1:2.
2. Berdasarkan analisis SEM, produk dihasilkan dengan adanya proses HTC memiliki morfologi berupa *microsphere*, sedangkan produk dari *direct carbonization* memiliki morfologi dengan bentuk *flakes*. Modifikasi berupa penambahan urea menghasilkan produk *N-doped hard carbon* dengan adannya aglomerasi, serta diameter *microsphere* yang lebih kecil.
3. Berdasarkan analisis komposisi sampel dengan metode EDS, *N-doping* berhasil dilakukan pada sintesis melalui proses HTC yang menghasilkan produk *N-doped hard carbon*. Selanjutnya, perubahan rasio massa pati terhadap urea dari 1:1 menjadi 1:2 meningkatkan komposisi nitrogen pada *N-doped hard carbon* dari 2,12% menjadi 3,08%. Sebaliknya, proses *direct carbonization* tidak memberikan *N-doping* pada produk *hard carbon*. Kemudian, sampel *N-doped hard carbon* dari proses HTC juga memiliki kandungan karbon yang lebih tinggi yaitu 90,12% dan 90,19% dibandingkan proses direct carbonization sebesar 87,29% dan 86,43% untuk rasio massa pati:urea 1:1 dan 1:2 secara berurutan.
4. Berdasarkan analisis XRD, produk *N-doped hard carbon* dari proses HTC dan *direct carbonization* memiliki *interlayer spacing* di rentang 0,362 hingga 0,382 nm, dimana *interlayer spacing* pada proses HTC sedikit lebih kecil dibandingkan *direct carbonization*. Selain itu, analisa kristalinitas XRD juga menunjukan bahwa produk *N-doped hard carbon* dari proses HTC juga memiliki komposisi *amorphous* yang lebih besar (mencapai 72,4% *amorphous*) dibandingkan dari proses *direct carbonization* (hanya mencapai 67,4% *amorphous*).

5. Berdasarkan analisis Raman *spectroscopy*, produk *N-doped hard carbon* dari proses HTC memiliki nilai ID/IG sebesar 1,26 dan 1,31 pada rasio massa urea:pati senilai 1:1 dan 1:2. Sedangkan, nilai ID/IG pada produk *direct carbonization* adalah 1,08 dan 1,13 pada rasio 1:1 dan 1:2. Akibatnya, dapat disimpulkan bahwa proses sintesis dengan HTC dan penambahan jumlah urea meningkatkan sifat *amorphous* dari produk *N-doped hard carbon*.

5.2. Saran

Untuk pengembangan kegiatan penelitian selanjutnya, terdapat beberapa saran yang dapat dipertimbangkan sebagai berikut.

1. Eksplorasi lebih jauh mengenai metode modifikasi pati untuk penambahan unsur nitrogen yang lebih efektif.
2. Analisis SEM (EDS) dan XRD terhadap sampel-sampel bahan baku pati, pati termodifikasi dan *hydrochar*. Selain itu, produk *N-doped hard carbon* juga dapat dianalisis dengan metode XPS dan FTIR untuk mengidentifikasi komposisi dan gugus fungsi nitrogen dengan lebih akurat.
3. Pengujian performa elektrokimia variasi sampel *N-doped hard carbon* sebagai material anoda *sodium-ion batteries* (SIB).

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